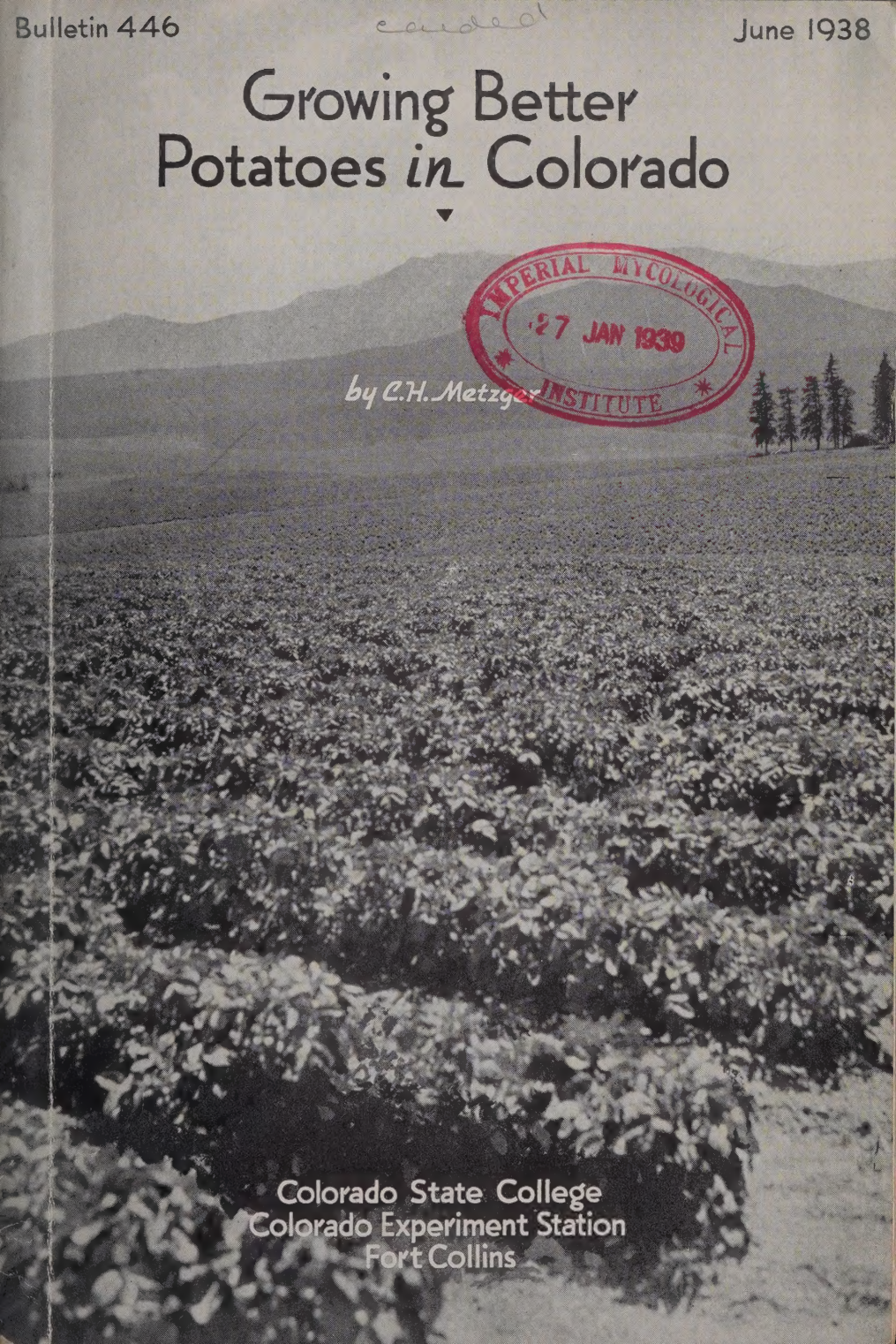
Bulletin 446

June 1938

Growing Better Potatoes *in* Colorado

IMPERIAL MYCOLOGICAL INSTITUTE
27 JAN 1939

by C.H. Metzger



Colorado State College
Colorado Experiment Station
Fort Collins

Bulletin 446 June 1938

Growing Better Potatoes *in* Colorado

C. H. Metzger

Colorado State College
Colorado Experiment Station
Fort Collins

Contents

	Page
Changes affecting the potato industry	5
Importance of potato production in Colorado	10
Trends in acreage, production, yields, and prices	11
Potato-growing districts	14
San Luis Valley	16
Northern Colorado	17
Western Slope	19
San Juan Basin	21
Northwestern Colorado	23
Front-Range	24
Plains Dry-Land	25
Climate and soil	26
Soil fertility	29
Rotation	30
Fertilizers	34
Suggested rotations	36
Soil preparation	37
Varieties for Colorado	39
Red McClure (Perfect Peachblow)	40
Smooth Rural	41
Russet Rural	42
Bliss Triumph	42
Brown Beauty (Prolific)	43
Irish Cobbler	44
Russet Burbank (Netted Gem, Idaho Russet)	45
Katahdin	47
Chippewa	48
Other promising varieties	48
Houma	48
Sebago	48
Earlaine	48
CS-110	48
Warba	48
Mesaba	48
Seed	49
Certified seed	51
Seed selection	54
Irrigated vs. non-irrigated seed	56
Whole vs. cut seed	57
Keeping seed until planting time	58

Contents

(Continued)

	Page
Potato diseases	59
Parasitic diseases	60
Rhizoctonia	60
Common scab	61
Blackleg	62
Fusarium wilt (oxysporum)	63
Fusarium (solani v. eumartii)	64
Early blight	64
Bacterial wilt	65
Virus diseases	65
Mosaic	65
Leaf roll	66
Spindle tuber	66
Curly dwarf	67
Witches broom	67
Giant Hill	68
Wilding (Heart leaf)	68
Pinto	69
Haywire	69
Seed treatment	71
Methods	72
Acid-mercury dip	73
Organic mercury compounds	73
Cutting seed	73
Planting	76
Date of planting	76
Planters	78
Depth of planting	80
Spacing	81
Cultivation	82
Hilling	83
Irrigation	85
Definitions	85
Use of water by the potato	85
When to irrigate	86
Flooding	87
Irrigating up	88
Amount of water to apply	88
Over-irrigation	90
When to stop irrigating	91
Irrigating from wells	91
Subirrigating	92
Summary of recommendations	93

Contents

(Continued)

	Page
Early potato production	94
Dry-land potato production	95
Soil preparation	96
Rotation	96
Planting	97
Spacing	98
Cultivation	98
Insects	98
Flea beetle	98
Psyllid	101
Grasshoppers	106
Blister beetles	106
Colorado potato beetle	107
Tarnished plant bug	108
Wireworms	108
Other insects	108
Jack rabbits	108
Harvesting	109
Diggers	111
Picking	112
Handling from field to storage	114
Full sacks	115
Storage	115
Temperatures	118
Humidity	119
Ventilation	120
Shrinkage	120
Light	120
Fumigation	120
Marketing	121
Grading	122
Cleaning tubers	123
Potatoes as feed for livestock	124
Potatoes for beef cattle	125
Potatoes for dairy cows	126
Potatoes for sheep	126
Potatoes for swine	126
Potatoes for horses	127

Cover Picture—A 50-acre field of Red McClure certified potato seed growing at an altitude of 9,300 feet, in the shadow of Pikes Peak.

Growing Better Potatoes *in* Colorado

C. H. Metzger

Many radical changes have taken place in the potato industry of the United States during the past 15 or 20 years. Production has materially increased in certain states and groups of states, while in others it has declined. As a result of this shift in production centers, Colorado growers have experienced keener competition from other states. The average yield per acre in the United States has steadily increased, while consumption has declined. The trucker has introduced a new method of transportation and merchandising. During the past year a serious attempt has been made to increase the consumption of potatoes through advertising. The federal government has attempted to remove surplus potatoes and will attempt to prevent the production of large surpluses. The national breeding program may also have a great influence on potato production of the future.

The percentage of the United States potato crop grown in the 18 surplus late states has increased during the past 15 or 20 years. This increase has been largely due to a quadrupling of production in Idaho, a doubling of production in Maine and Colorado, and a 30-percent increase in North Dakota. Production in Pennsylvania, Minnesota, Nebraska, Washington, Oregon, and Wyoming has changed but little, while New York, Michigan, Wisconsin, California, South Dakota, Utah, Montana, and Nevada show decreases in production. New York, Michigan, and Wisconsin are making serious attempts to stop the decline, and California seems to be bounding upward with a tremendous increase in early and intermediate potatoes from the Shafter district.

In the 12 other late states, production has declined considerably during the past 20 years, due largely to low yields and a superior-quality product from other states. Illinois produces only one-third as many potatoes as formerly, Iowa one-half, and Indiana two-thirds. Production in Ohio, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, West Virginia, New Mexico, and Arizona has also declined to some extent.

The seven intermediate states—New Jersey, Delaware, Maryland, Virginia, Kentucky, Missouri, and Kansas—have maintained their production as a group during the 20-year period.

The 11 early states as a group have increased production considerably during the past 20 years. North Carolina, Florida, and Oklahoma have doubled their production. Louisiana and Texas have increased production one-third, while South Carolina, Tennessee, Alabama, and Arkansas have shown smaller increases. Production in Georgia and Mississippi has remained constant.

These shifts in production are of considerable importance to Colorado growers, because with changes in production in competing states and improvements in transportation and marketing, almost any of the other 47 states may become competitors of Colorado. Nebraska, Wyoming, and Idaho potatoes compete with Colorado potatoes in nearly all the markets to which Colorado ships. Texas receives more Colorado potatoes than any other state. In 1931 Maine started shipping potatoes by water to gulf ports, and another competitor was thus added to the list. A large volume of new potatoes now arrives on the markets in April from Florida, California, Texas, and Alabama. These new potatoes compete with old stocks still in storage, and this will probably mean that some Colorado growers will be forced to change present practices and dispose of their potatoes by the middle of April.

TABLE 1.—*Rank of leading potato-producing states, with production, acreage, yield, and carlot shipments.**

State	Production average 1928-32	Acreage harvested average 1928-32	Yield average 1923-32	Shipments average 1926-35
	Bushels	*Acres*	*Bushels*	*Cars*
1. Maine	44,078,000	175,000	258	48,175
2. Minnesota	29,620,000	353,000	93	18,978
3. New York	27,942,000	230,000	118	9,895
4. Pennsylvania	24,653,000	214,000	112	1,693
5. Wisconsin	24,311,000	261,000	100	12,630
6. Michigan	23,371,000	257,000	99	9,181
7. Idaho	21,723,000	104,000	200	24,534
8. Colorado	14,584,000	104,000	149	12,165
9. Virginia	14,328,000	109,000	126	18,136
10. Ohio	11,435,000	119,000	96	231
11. Nebraska	9,526,000	117,000	82	6,516
12. North Dakota	8,807,000	126,000	76	6,583
13. Washington	8,047,000	51,000	162	7,051
14. California	7,718,000	41,000	185	8,301
15. North Carolina	7,540,000	74,000	98	7,793
United States	372,115,000	3,327,300	112.7	222,643

*U.S.D.A. Agricultural Statistics, 1937.

One of the most vital changes affecting the potato industry has been the reduction in per-capita consumption and the simultaneous increase in average yield to the acre in the United States. The average yield to the acre has increased from 94.4 bushels in the period 1915-19 to 113.6 bushels in the 5-year period 1925-29. This means that acreage must be reduced about 15 percent to prevent overproduction. In addition to the increase in average yield per acre, the per capita consumption has dropped from 3.5 bushels to about 2.8 bushels. This decrease is due largely to increased competition from fresh fruits and vegetables. There have been tremendous increases in the production of head lettuce, cauliflower, pod peas,

and citrus fruits, and these increases have been partly at the expense of potatoes. A human being can consume a limited amount of food—an amount estimated at 1,355 pounds annually—and when he increases his consumption of one commodity it is usually at the expense of some other commodity. The publicity on vitamins and their occurrence in fresh fruits and vegetables, and the diet fads, have done much to stimulate consumption of these fresh fruits and vegetables.

In 1930 a 360,000,000-bushel crop of potatoes was produced, and the December price to growers was $1 a hundredweight. At the present time any crop much greater than 360,000,000 bushels will not bring satisfactory prices to growers. A study of table 2 will show the relation between the size of the United States crop and the price received by growers.

The trucker has introduced a new method of transportation and marketing potatoes. A few years ago there was considerable opposition to the trucker, but this opposition seems to be diminishing as certain regulations have been made and as the trucking business has emerged from its boom period and become stabilized. Truck transportation has made possible the growth of the potato industry in the San Juan Basin and in other isolated parts of Colorado. In 1936, 12.6 percent of the San Luis Valley potato crop was moved by truck, and to February 1, 1937, about 20 percent of the movement had been by truck. In Michigan practically the entire potato supply of the city of Detroit is now provided by trucks, and in Colorado much the same situation exists in Denver. The trucker has been severely criticized for hauling and selling a poor-quality product. This is not altogether the trucker's responsibility, as some unscrupulous farmer sold the trucker these potatoes. It is believed that the trucker is handling better quality stock than formerly. A Colorado state law prohibiting the sale of culls is contemplated.

During the past year programs have been inaugurated to advertise potatoes in the newspapers and magazines and over the radio, with the object of increasing consumption and correcting some erroneous ideas regarding their use in the diet. Maine has placed a tax on each sack of potatoes sold and collects nearly $100,000 a year. Idaho has made a similar attempt, but litigation has prevented much progress to date.

The National Potato Publicity Board is supported by voluntary contributions and has a very impressive record for its first year of operation. This organization has stated that a family of four in the low-income group should use 11 pounds of potatoes per week, while in the liberal-income group a family of four should use 9 pounds of potatoes per week. On this basis, a goal of production for the United States of 425,000,000 bushels to 450,000,000 bushels has been established. About 82 percent of present potato production is used

TABLE 2.—*Potato production, acreage, yield, carload shipments, and prices for Colorado and the United States from 1920 to 1937, inclusive.*

Year	Colorado*					United States†				
	Acreage harvested	Production	Average yield to the acre	Price bushel	Shipments	Acreage harvested	Production	Average yield to acre	Price bushel	Shipments
	Thousand acres	*Thousand bushels*	*Bushels*	*Cents*	*Cars*	*Thousand acres*	*Thousand bushels*	*Bushels*	*Cents*	*Cars*
1920	73	9,855	135	0.80	11,229	3,301	368,904	111.8	132.8	185,176
1921	113	14,916	132	0.73	17,697	3,598	325,312	90.4	112.8	218,001
1922	136	19,040	140	0.37	15,467	3,946	419,288	106.3	68.2	245,407
1923	96	11,808	123	0.53	13,870	3,378	366,356	108.5	91.4	241,603
1924	72	10,440	145	0.60	12,386	3,106	384,166	123.7	71.2	252,097
1925	62	12,090	195	1.55	15,422	2,810	296,466	105.5	165.8	241,523
1926	76	11,020	145	1.30	14,200	2,811	321,607	114.4	136.1	332,424
1927	99	16,335	165	0.55	17,328	3,182	369,644	116.2	108.5	253,445
1928	114	17,670	155	0.45	13,714	3,499	427,249	122.1	57.1	257,343
1929	90	14,670	163	1.14	15,366	3,019	332,204	110.0	131.8	253,194
1930	94	17,860	190	0.69	18,080	3,103	340,572	109.8	91.8	252,411
1931	106	10,070	95	0.33	7,529	3,467	384,125	110.8	46.3	241,003
1932	115	12,650	110	0.24	7,266	3,549	376,425	106.1	39.2	199,358
1933	98	14,700	150	0.48	12,395	3,412	342,306	100.3	82.1	204,082
1934	93	7,812	84	0.59	3,265	3,597	406,105	112.9	44.8	223,612
1935	100	18,000	180	0.60	12,505	3,541	386,380	109.1	59.7	202,321
1936	100	18,500	185	1.05	15,616	3,058	329,997	107.9	111.3	211,580
1937	106	15,688	...	...	....	3,224	391,159	....	....	.....

*Colorado Agricultural Statistics, 1935.
†U.S.D.A. Agricultural Statistics, 1937.

as human food; the remainder is used as seed and as feed for livestock or is lost through shrinkage, decay, dumping, or culling.

The 1937 potato crop was large enough to bring about ruinous prices, but a federal program of diversion to livestock feed and manufacturing through marketing agreements maintained fairly satisfactory prices. In Europe enormous quantities of potatoes are used as livestock feed and in the manufacture of starch, flour, and alcohol. It is possible that such uses may increase in the United States. The 1938 soil conservation program sets up acreage goals for potatoes with the object of limiting United States acreage to between 3,100,000 and 3,300,000. Such a limitation of acreage, if successfully accomplished, should prevent any enormous surpluses; but weather has much more influence on the size of the crop than has acreage, as is readily revealed by a study of table 2. A program of acreage limitation and the use of marketing agreements to divert a portion of the crop in years of surplus might stabilize prices and prevent the wide fluctuations in price which seem so detrimental to the industry at present, both from the grower's and the consumer's viewpoints. High prices such as those of 1919, 1925, 1926, and 1936 cause curtailment of consumption and substitution of other foods for potatoes; and the ultimate effect is worse than that of disastrous-price years such as 1922, 1928, or 1932.

In any consideration of future developments in the potato industry, the national potato-breeding program is extremely important. The development of potato varieties of better market quality, and of varieties adapted to or tolerant of unfavorable environmental conditions, may cause a shift in production to areas closer to the large consuming centers. The release of new varieties resistant to one or more serious diseases may also have a marked influence on the potato industry. Varieties resistant to scab have already been obtained, and the combining of scab resistance and good commercial quality should occur shortly. This will mean that a higher percentage of the crop will be marketable. In the spring of 1938 a new potato variety was released which shows some resistance to late blight. This means lower costs of production in humid states where late blight occurs, as only three applications of spray are necessary, whereas from 10 to 14 applications are necessary on present commercial varieties. Mosaic will also undoubtedly decrease in importance, as all new varieties so far introduced show some degree of resistance to this disease.

From the foregoing discussion it will be realized that many changes are occurring in the potato industry. It is necessary for Colorado growers to be aware of the changes and to keep abreast of them—or better yet, to keep ahead of them. Colorado has an ideal soil and an ideal climate for potato production. Just as high yields can be obtained in Colorado as can be obtained anywhere, and the quality produced is better than that of most growing dis-

tricts. Because he is quite distant from large consuming centers, the Colorado grower must keep his costs down by obtaining high yields of quality potatoes. It has often been said that the potato enterprise cannot be profitable unless double the present average yield is obtained. In order to obtain double the average yield, it is necessary to plant only the best seed obtainable. Organic matter must be incorporated into the soil. A rotation must be established, including alfalfa and the application of manure. Diseases and insects must be controlled. Better stands must be secured. Only standard varieties for the district may be planted. Bruising in harvesting and storage must be reduced to a minimum. In other words, the Colorado grower must produce a better potato at less cost than his competitor if he is to stay in business and hold his market. This bulletin outlines the best known methods of production, and it is only by following them that Colorado's position as a potato-producing state can be maintained.

Importance of Potato Production in Colorado

Colorado ranks eighth in potato production among the states, with an average 10-year (1926-35) annual production of 14,078,700 bushels and an average acreage of 98,500 for the same period. The figures for the important states are given in table 1. The value of the potato crop is nearly double that of all other vegetables produced in the state; in 1936 it was $19,425,000, which was 20 percent of the value of all crops produced in the state that year. The average valuation of the state's potato crop for the 10-year period 1926-35 was $8,913,315; it was exceeded in value only by corn, hay, sugar beets, and wheat. According to the 1930 census, 15,043 farms, or 25 percent of all farms in the state, grow potatoes. The average acreage per farm is 5.94. Potatoes occupy only 1.5 percent of the harvested area of the state. Colorado has about 3 percent of the United States acreage but produces about 4 percent of the United States crop. Only 82 percent of the Colorado acreage is irrigated; 18 percent is dry land, which considerably reduces the average yield for the state.

The average yield for the state is only 143.7 bushels, despite the exceptionally high yields often obtained. The 18 percent consisting of dry-land acreage is only partly responsible for this low yield. To great extent it is due to unadapted locations and to unadapted growers starting production following high-price years. In part it is also due to periodic unfavorable climatic conditions such as moisture shortage, high temperatures, and epidemics of psyllid yellows. The states in which the average yield to the acre exceeds that of Colorado are Maine, 260.4 bushels; Idaho, 207.6 bushels; California, 197.3 bushels; New Jersey, 169.8 bushels; Washington, 169.7 bushels; Rhode Island, 153.8 bushels; and New Hampshire, 153.0 bushels. During the past 3 years, however, the Colorado average has been

above 170 bushels; this puts the state in fourth place, where it should rightfully remain if growers follow the better methods of production. Growers on irrigated land should not be satisfied with less than 300 bushels (180 sacks) to the acre, and growers on dry land should obtain at least 100 bushels (60 sacks) to the acre.

Colorado is quite close to good markets to the south and east. Texas receives more Colorado potatoes than any other state. About 60 percent of the Colorado crop is shipped, and the state ranks sixth in carlot shipments. The average 1926-35 carlot shipments for the leading states are shown in table 1. Most Colorado shipments consist of varieties not grown in other states, and this lessens competition on the market. The Red McClure from Colorado again brought a higher price in Chicago than any other variety from any other state in 1937. The car-lot shipments by years since 1920 are given in table 2.

Trends in Acreage, Production, Yields, and Prices

Potato acreage in Colorado has shown a steadily upward trend since 1880. The decline in acreage during the 5-year period 1915-19 was a reaction from the failures during the previous 5-year period. In 1910 the acreage in the state had risen to 90,000, but the average yield was only 104 bushels. In 1911, however, the real disaster occurred as a result of epidemic, the average yield on 84,000 acres being only 64 bushels. The season of 1912 was more favorable; but the epidemic persisted, and in 1913 the average yield was only 91 bushels. The acreage declined until 1917, when the World War forced the average upward again; but it was not until 1921 that the acreage again exceeded 90,000. These decreases were undoubtedly due to psyllid yellows, although the insect was not associated with the trouble until 1928. A similar epidemic had occurred between 1900 and 1903, although there were probably others earlier than this time, as the average yield in 1889 was only 55 bushels. The peak during the 5-year period 1920-24 is due to large acreages in 2 of the 5 years. In 1921, 113,000 acres were planted; and in 1922, 136,000 acres were planted, which is the largest acreage ever planted in the state.

The United States crop in 1922 was the largest on record up to that time, resulting in extremely low prices and the "dumping" of a part of the crop. Acreage declined to 62,000 acres in 1925, when the United States crop was small, resulting in very favorable prices. Acreage again increased until 1928, when the United States crop was the largest on record, and again prices were low; the markets could not absorb all the potatoes produced, and many were dumped. The United States acreage has shown a steady increase with the increase in population, reaching its peak in the period between 1910 and 1914. The trend since that time has been toward a slightly

lower acreage, largely because of curtailed consumption and an increase in the average yield.

The low acreage during the 5-year period 1925-29 resulted in the most prosperous era in the history of the potato industry, prices being good in all years except 1928. The trends in acreage for Colorado and for the United States are shown in figure 1.

The increase in production in Colorado, like the increase in acreage, has been almost continuous since 1880. The drop during

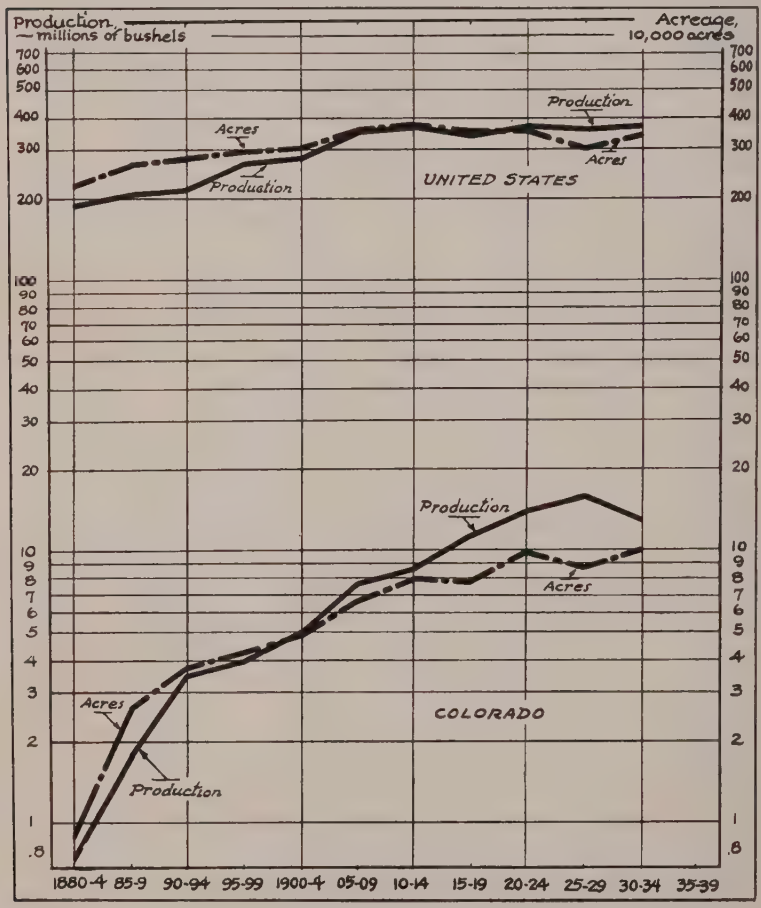


Figure 1. Acreage and production trends in Colorado and the United States by 5-year periods. These are logarithmic curves; the slope of the lines indicates the percentage increase or decrease from the previous 5-year period. Production is above acreage when yields are greater than 100 bushels to the acre.

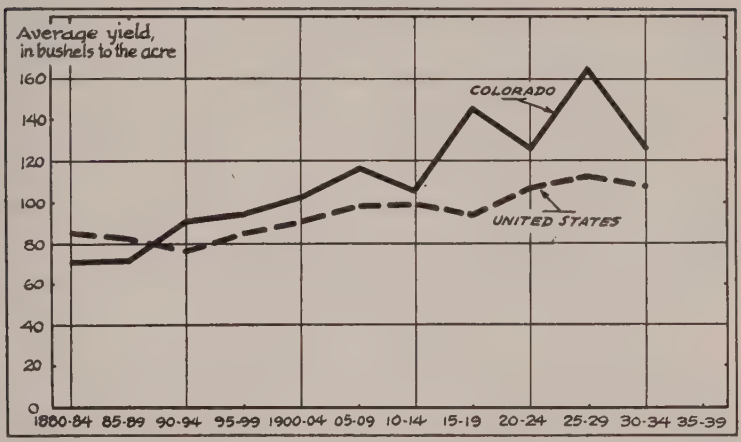


Figure 2. Yield trends in Colorado and in the United States by 5-year periods.

the last 5-year period, shown in figure 1, was due to 3 years of low yields caused by drought. The fact that weather has far more influence on production than has acreage was well illustrated during this period. The acreage in 1930 was 11.3 percent lower than in 1931, while production was 78 percent greater. The acreage in 1935 was only 7.5 percent above that of 1934, but production in 1935 was 130 percent greater than in 1934. Production in the United States showed a steady increase until the 5-year period 1915-19. In this period two very small crops, one in 1916 and the other in 1919, accounted for the lower average production, despite a large crop in 1917. The next 5-year period (1920-24) showed the highest average production of any to date and is noteworthy because of the large crops of 1922 and 1924. The 5-year period 1925-29 shows a lower average production because of three small crops in 1925, 1926, and 1929 and despite the largest crop on record in 1928. In the last 5-year period (1930-34) there were no very small crops, and the crops in 1931 and 1934 were large. Production trends in Colorado and the United States are shown in figure 1.

The average yields to the acre for Colorado and the United States are shown in figure 2. The psyllid yellows epidemic, in the period 1910-14, caused a halt in the upward trend. In 1911 the average yield was only 64 bushels; in 1913 it was 91 bushels; and in 1910 it was 104 bushels. The lower average in the period 1920-24 was caused by yields slightly below average in each year, the lowest being 123 bushels to the acre in 1923, and by the fact that in none of these 5 years was the yield above average, the highest being 145 bushels in 1924. During the next 5-year period, 1925-29, the average yield was the highest to date. In 1925, 195 bushels to the acre were

produced, the highest yield on record. Yields throughout this period were high, the lowest being 145 bushels in 1926. The average for the last 5-year period was the lowest since 1910-14, because of drought and psyllids. The yield in 1930 was 190 bushels—next to the highest on record—but in 1934 the yield was only 84 bushels; in 1931 it was only 95 bushels, and in 1932 it was only 110 bushels.

The average price received by growers in Colorado by 5-year periods is shown in figure 3. The high prices during the first period were due to great activity in the mining industry, lack of adequate transportation, and the small supply of potatoes. For the following 30 years growers received an average price of 95 cents a hundredweight. The next 15 years were very prosperous ones for the indus-

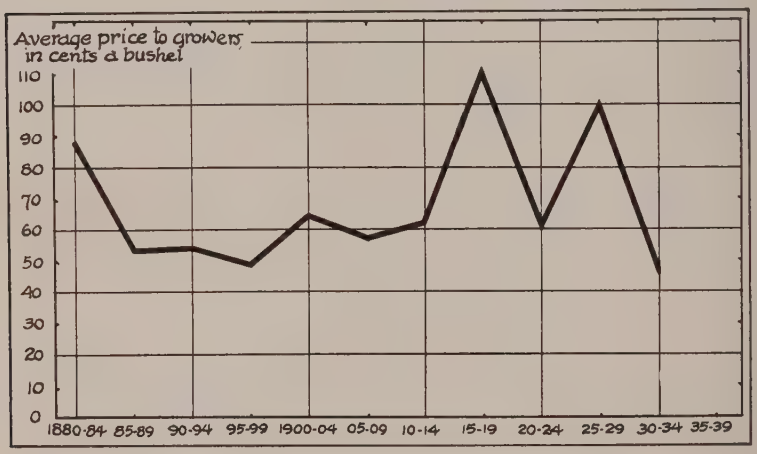


Figure 3. Price trends in Colorado by 5-year periods.

try, as the average price to growers was $1.50 a hundredweight. During the last 5 years the average price to growers has been the lowest in history. Prices during this period have been influenced not only by the size of the national crop but also by economic conditions. The peaks and depressions during the past 20 years are determined to a large extent by the small United States crops of 1916, 1919, 1925, 1926, and 1929 and by the large crops of 1922, 1924, and 1934. Economic conditions were favorable during the 1915-19 and 1925-29 periods and unfavorable during the 1920-24 and 1930-34 periods.

Potato-Growing Districts

Potatoes are grown in all parts of Colorado, but there are three main commercial districts and four districts of less importance. Some of the mountain counties do not produce many potatoes, because of a limited amount of agricultural land or because of a dom-

inance of meadow land and the absence of general farming. In other areas potato growing has not been successful over a period of years, although some of these areas were important production centers in the early days. The areas in which potatoes have frequently failed include a strip about 15 miles wide from north to south along the foothills of the mountains on the Eastern Slope. Included are Virginia Dale, Fort Collins, Longmont, Boulder, Denver, the Fountain Valley south of Colorado Springs, and the entire Arkansas Valley. Soils and climatic conditions are not different in these areas

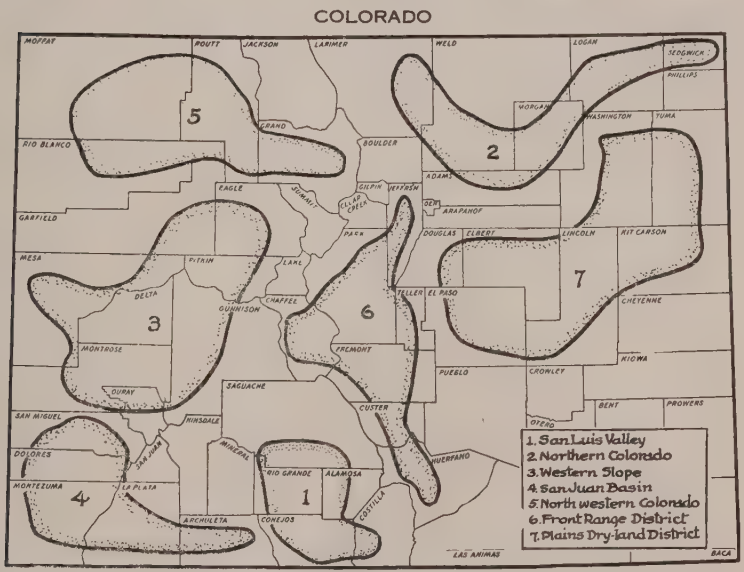


Figure 4. Potato-growing districts of Colorado.

from those in other areas where potatoes are successfully produced. During the past 2 years the Colorado Experiment Station has successfully grown potatoes at Fort Collins by spraying three times with liquid lime sulfur, proving that the failures in these areas are due to psyllids. The potato-growing districts of the state are shown in figure 4.

While a few areas in the state have declined in potato production, the increase in other areas has been spectacular. Hundreds of thousands and even millions of acres of excellent potato land are still undeveloped and need only water to bring them into production. Other excellent sections need only adequate and cheap transportation to make them first-rate commercial districts. Some of these lands will probably never be developed because of an inadequate water supply, but potato production will probably increase

in Colorado for some time to come. The size and importance of the industry in the state are shown in table 3.

TABLE 3.—*Census figures for the potato industry in Colorado.*

Production 1929	Acreage 1934	Acreage 1929	Acreage 1919	Number farms reporting potatoes, 1929	Average yield to acre 1923-32*
Bushels	*Acres*	*Acres*	*Acres*	*Farms*	*Bushels*
14,649,446	92,925	89,692	77,337	15,043	149

*Colorado Agricultural Statistics, 1935.

San Luis Valley

The San Luis Valley potato district was of only minor importance 25 years ago, but at the present time it produces more than half the potatoes of the state. Rio Grande County ranks fourth in the United States in production. The San Luis Valley consists of five counties, is 120 miles long and 60 miles wide, and contains more than 3,000,000 acres. Less than one-fourth of this area is under cultivation. The annual precipitation is less than 10 inches, and all crops are produced under irrigation. Potatoes are produced at altitudes of from 7,500 feet to 8,500 feet. The valley is surrounded by mountains, but the floor of the valley is quite level. The Rio Grande River heads in the mountains on the west side of the valley, and supplies irrigation water for the district. It is believed that the entire valley is an old lake bed. The soils are generally sandy or gravelly loams, with a few heavier soils. They are mostly quite

Figure 5. Harvesting 1,145.17 bushels of Brown Beauty potatoes from a measured acre on the farm of L. G. Schutte, in the San Luis Valley; the yield is the result of plowing under sweet-clover and planting certified seed.

alkaline, running in pH from 7.5 to nearly 9.0. The tubers are generally "netted" or flaked, and quite clean.

The highest yields in the state have been produced in this district. L. G. Schutte of Monte Vista (fig. 5) produced 1,145.17 bushels on a measured acre in 1929, which was the American record until 1933 when Zuckerman Brothers at Stockton, Calif., obtained 1,155.83 bushels. The chief varieties produced are Red McClure, Brown Beauty, Triumph, and Russet Burbank. This district plants more certified seed than all the rest of the state combined, and yields and quality are rapidly improving. Recent tests show that many soils in the valley are deficient in nitrates. More alfalfa must be planted and more barnyard manure must be applied to these soils in order to maintain their productiveness. There is also a tendency to plant potatoes too often on the same ground. The census figures in table 4 show the size and importance of the potato industry in this district.

TABLE 4.—*Census figures for the potato industry in the San Luis Valley.*

County	Production 1929	Acreage 1934	Acreage 1929	Acreage 1919	Number farms reporting potatoes, 1929	Average yield to acre 1923-32*
	Bushels	*Acres*	*Acres*	*Acres*	*Farms*	*Bushels*
Rio Grande.....	4,424,489	21,052	19,655	12,317	586	181
Saguache	1,603,477	8,204	7,353	2,233	287	167
Conejos	957,927	7,772	5,221	1,942	548	156
Alamosa	1,103,727	5,506	5,754	2,714	318	160
Costilla	37,429	528	291	230	127	133
Total	8,127,049	43,062	38,274	19,436	1,866	171

*Colorado Agricultural Statistics, 1935.

Northern Colorado

The principal center of production in the Northern Colorado potato district is Greeley, one of the most famous producing centers in the United States. It is the oldest commercial center in the state. Production started in 1870 and reached its peak in 1909. At its height, between 4 and 6 million bushels were produced, and between 8,000 and 14,000 cars were shipped annually. In 1911 a disaster in the form of an epidemic, which hardly has a parallel in potato history, overtook this district. The entire state produced only about 3,000,000 bushels that year, mostly on the mountain mesas, and the northern Colorado crop was almost a total loss. This epidemic lasted until 1915, when a normal crop was produced on a greatly reduced acreage. The cause of this epidemic was undoubtedly the tomato psyllid, although the connection between the insect and the disease now known as psyllid yellows was not estab-

lished until 1927. This epidemic was a serious blow, and the Greeley district has never regained its former prominence.

The district contains six counties, and most of the potatoes are grown in the South Platte and Cache la Poudre Valleys, although there is some dry-land acreage in all the counties. The soils vary widely from sandy loams to clay loams; they are mostly alkaline, varying in pH from 6.5 to 8.5. The altitude is between 4,000 and 5,000 feet. Both early and late potatoes are produced. The "earlies," grown mostly around Gilcrest, Fort Lupton, Brush, and Fort Morgan, are marketed as early as the last week in June and continue

Figure 6. An Irish Cobbler field in bloom in the Northeastern district.

coming upon the market until September. The late crop is not dug until October and conflicts to a considerable extent with the sugar-beet harvest. Most of the crop is now moved by truck, a large portion going to the Denver market. The chief varieties are Rural, Russet Rural, Triumph, Cobbler, and Katahdin.

The district has had many difficulties in potato production in addition to those already mentioned. The summer temperature occasionally gets high enough to reduce yields; most of the stands are below average; fusarium wilt is more prevalent than in any other part of the state; and spindle tuber spreads very rapidly. This district is the native habitat of the Colorado potato beetle, and flea beetles which "worm track" the tubers are plentiful. Some of the soils are very heavy and difficult to handle. Growers often plant too late for the crop to mature, and tubers are skinned and bruised.

Many changes are necessary before this district can compete with the leading commercial districts of the United States. Importing certified foundation seed from dry land or mountains will reduce the fusarium discoloration in the tubers and the amount of spindle tuber. A regular spray program must be adopted to control insect pests and particularly to reduce the "worm track" on the tubers. Plowing under coarse litter such as corn will increase the productivity of the heavy soils. Every effort should be made to improve stands. Late varieties must be planted earlier, and irrigation should cease in time for the tubers to mature. More care in harvesting and storing is necessary. More careful grading is necessary, and new branded bags would add much to the appearance of the product. Statistics for this district are given in table 5.

TABLE 5.—*Census figures for the potato industry in northern Colorado.*

County	Production 1929	Acreage 1934	Acreage 1929	Acreage 1919	Number farms reporting potatoes, 1929	Average yield to acre 1923-32*
	Bushels	*Acres*	*Acres*	*Acres*	*Farms*	*Bushels*
Weld	2,657,520	19,950	22,767	15,622	1,762	155
Sedgwick	43,587	953	400	777	87	120
Morgan	285,688	837	1,442	1,250	180	164
Logan	66,158	511	954	241	524	83
Larimer	45,751	484	578	543	234	133
Adams	30,426	103	312	1,286	106	111
Total	3,129,130	22,838	26,453	19,719	2,893	149

*Colorado Agricultural Statistics, 1935.

Western Slope

The Western Slope potato-producing district consists of eight counties. Potato growing is confined to the Eagle, Colorado, Crystal, Gunnison, and Uncompahgre Valleys. The district is a unit from the standpoint of geography and marketing but from the viewpoint of production is separated into two parts, production in the upper valleys being quite different from that in the lower valleys. Altitudes in this district range from 4,500 to 9,000 feet. The mesa and lighter types of soils produce excellent-quality potatoes, but some of the heavier soils in the river bottoms present a serious problem. The soils vary in color from black through gray to tan and brown and to bright red. These red soils are rather limited in extent and are confined mainly to the Gypsum and Crystal Valleys. They produce the famous red-soil Russet Burbanks which bring the highest price of any potato in the United States and are sold mainly on the Denver market. The soils range from slightly acid to quite alkaline, the pH running from 6 to 9. The lower valleys in this district have

the mildest climate in the state, and a considerable volume of early potatoes is produced in this area. Plantings are made about the first of April, and harvesting starts as early as the last week in June. The earliest potatoes are grown around Fruita and Loma, in Mesa County, and the area for their production extends up the Gunnison Valley through Delta and Olathe to Montrose.

Ample water is available from the streams throughout this district, and at the higher elevations there is ample precipitation to produce satisfactory yields without irrigation. This district has the highest average potato yield in the state. Eagle, Garfield, and Pitkin Counties lead all other counties in average yield to the acre. Bost-

Figure 7. By use of alfalfa, manure, and certified seed, yields of 300 sacks to the acre are maintained at the Mountain Substation, in the Western Slope district.

wick Park, in Montrose County, is famous for its high yields, and most of the growers in this park are members of the Colorado 600-Bushel Club. The main varieties grown in this district are the Rural, Russet Burbank, Triumph, Cobbler, Russet Rural, and Katahdin.

The seed stock in this area has not been maintained so well as that in other leading commercial districts. Seed stocks should be renewed oftener in order to avoid difficulties caused by such diseases as spindle tuber, leaf roll, mosaic, "rhizoc," scab, and fusarium. These diseases are responsible for the poor appearance of a majority of the potatoes grown in this district. Recent tests by the Colorado Experiment Station have demonstrated that potatoes of the best chemical composition and cooking quality are produced in this district, but it is imperative that the appearance and grade of the tubers be improved. A serious objection to potatoes from this dis-

trict is the amount of earth adhering to them. It is necessary to incorporate more organic matter in these soils in order to eliminate dirty tubers.

It is recommended that bromegrass be seeded with alfalfa, that more barnyard manure be applied to the soil somewhere in the rotation, and that potatoes shall not be grown on the same ground oftener than once in 5 years.

Because of the abundance of water in this district, many growers over-irrigate potatoes, as is demonstrated by the enlarged lenticels and the prevalence of fusarium wilt, especially at the lower elevations. If irrigation is not stopped in time to permit the tubers to mature, they are usually extremely tender; they skin and bruise very easily, and this detracts considerably from their appearance. Potatoes should be planted closer together in some parts of this district to prevent oversize and hollow heart. Psyllids and flea beetles have caused considerable damage to potato crops, and a regular spray program should be adopted to control these insects. The best practices for this district have been demonstrated at the Mountain Substation at Avon. A potato harvesting scene at this station is shown in figure 7. The importance of potato production on the Western Slope is shown in table 6.

TABLE 6.—*Census figures for the potato industry on the Western Slope.*

County	Production 1929	Acreage 1934	Acreage 1929	Acreage 1919	Number farms reporting potatoes, 1929	Average yield to acre 1923-32*
	Bushels	*Acres*	*Acres*	*Acres*	*Farms*	*Bushels*
Montrose	877,089	5,104	4,282	7,079	678	172
Garfield	548,508	2,652	2,616	2,856	489	182
Mesa	170,336	2,205	1,363	1,619	695	134
Eagle	293,769	1,485	1,133	1,584	182	197
Delta	136,180	1,007	851	2,916	547	154
Pitkin	196,872	878	960	921	121	187
Gunnison	42,254	298	241	384	169	112
Ouray	25,718	213	221	273	114	122
Total	2,290,726	13,842	11,667	17,632	2,995	174

*Colorado Agricultural Statistics, 1935.

San Juan Basin

Potato production in the San Juan Basin district is increasing very rapidly and has doubled since 1929. Both seed and table stock are produced. Most of the potatoes are moved by truck to markets to the south. Potatoes are grown at altitudes ranging from 6,200 to 10,000 feet. Since this is a new farming area, the soils are friable, very fertile, and easily handled. Some of the potatoes in Montezuma and La Plata Counties are grown under irrigation. A large part of

the production is non-irrigated in the higher mountain areas and in western Dolores and San Miguel Counties. Precipitation ranges from 20 to 35 inches annually. The leading potato varieties are Cobbler, Katahdin, and Triumph. There is still plenty of room for expansion of the industry in the area, and many drought refugees from eastern Colorado, Nebraska, Kansas, Oklahoma, and Texas have settled in this district. As would be expected in a new area, diseases and insects are not very prevalent at the present time. Fusarium wilt causes some damage at the lower elevations. It is recommended that the Triumph variety be planted in these sections

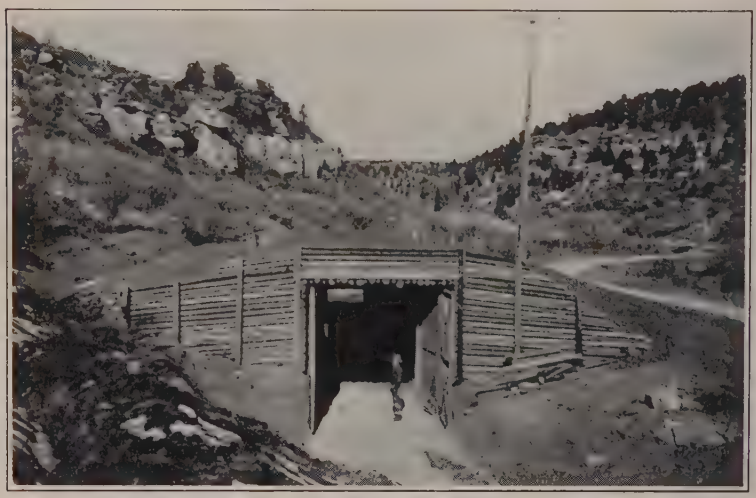


Figure 8. Increase in potato production in the San Juan Basin has resulted in construction of many new cellars of this type.

TABLE 7.—*Census figures for the potato industry in the San Juan Basin.*

County	Production 1929	Acreage 1934	Acreage 1929	Acreage 1919	Number farms reporting potatoes, 1929	Average yield to acre 1923-32*
	Bushels	*Acres*	*Acres*	*Acres*	*Farms*	*Bushels*
Montezuma	77,094	2,094	777	409	449	100
La Plata.....	92,163	999	840	881	578	122
Dolores	12,747	412	169	86	82	59
San Miguel.....	18,269	318	154	181	114	87
Archuleta	17,536	144	194	286	172	84
Total	217,809	3,967	2,134	1,843	1,395	105

*Colorado Agricultural Statistics, 1935.

instead of the Cobbler. Psyllid yellows occasionally causes some damage, a severe epidemic having occurred in 1937. Growers should be prepared to spray their fields. The flea beetle is present, but it has not as yet caused any material damage. In the lower, drier areas, potato yields could be materially increased by summer fallowing. The size and importance of the potato industry in this area are shown in table 7.

Northwestern Colorado

Potato production in the Northwestern Colorado section is increasing rapidly, having doubled since 1929. Due to better trans-

Figure 9. Potato production is increasing in the Northwestern district; note the spacing in this dry-land field in Moffat County.

portation facilities through the Moffat Tunnel and also to better freight rates, car-lot shipments are increasing. The soils are well suited to potato production and have not been heavily cropped, since livestock production is the leading industry. The amount of irrigated land in this area is quite limited, but there is ample rainfall in most parts. The average annual precipitation at Steamboat Springs is 24 inches, the fall being distributed almost evenly throughout the year—that is, 2 inches a month. However, in Moffat County, in the western part of the district, summer fallowing would undoubtedly be of benefit. Potatoes in this district are grown at altitudes of from 6,000 to 8,000 feet. Both seed and table stock are produced. There are thousands of acres of undeveloped potato land in this area, and many drought refugees have recently moved to this district. The Triumph variety is grown almost exclusively, although there are a few Cobblers, Red McClures, and Katahdins.

The leading difficulties in potato production in this area are scab and "rhizoc." Growers should treat their seed every year and follow a crop rotation in which potatoes are not grown on the same ground oftener than once in 5 years, in order to keep these diseases at a minimum. The growth of the potato industry of this district is indicated in table 8.

TABLE 8.—*Census figures for the potato industry in northwestern Colorado.*

County	Production 1929	Acreage 1934	Acreage 1929	Acreage 1919	Number farms reporting potatoes, 1929	Average yield to acre 1923-32*
	Bushels	*Acres*	*Acres*	*Acres*	*Farms*	*Bushels*
Routt	120,658	1,543	958	589	478	87
Moffat	48,964	758	544	785	421	69
Rio Blanco.....	12,044	153	96	176	168	118
Grand	7,862	100	80	86	67	100
Total	189,528	2,554	1,678	1,636	1,134	85

*Colorado Agricultural Statistics, 1935.

Front-Range

Most of the potatoes in the Front-Range district are grown for seed or for local markets. Most of the production is on dry land. A typical field is shown in figure 10. The average altitude of this district is the highest in the state, potatoes being grown at altitudes of from 7,000 to 10,000 feet. The leading varieties are Red McClure,

Figure 10. A typical field in the Front-Range district. Most of the potatoes in this district are grown at altitudes of between 7,000 feet and 10,000 feet.

Triumph, and Cobbler. Psyllid yellows occurs practically every year in this district, so spraying must be incorporated as a part of the potato-growing program. Considerable difficulty has also been experienced with "haywire" in the seed potatoes from this area. Where psyllid yellows has been controlled by spraying, haywire has not been evident in the seed stock. Production in this district has remained practically constant, as is shown by the figures in table 9.

TABLE 9.—*Census figures for the potato industry in the Front-Range district.*

County	Production 1929	Acreage 1934	Acreage 1929	Acreage 1919	Number farms reporting potatoes, 1929	Average yield to acre 1923-32*
	Bushels	*Acres*	*Acres*	*Acres*	*Farms*	*Bushels*
Park	103,213	1,865	1,351	969	203	52
Teller	110,764	1,633	1,315	1,100	191	70
Custer	166,556	832	1,482	1,182	239	72
Fremont	24,617	430	318	529	84	58
Chaffee	48,670	283	398	698	164	109
Jefferson	44,965	250	510	962	280	79
Huerfano	13,070	218	167	163	57	67
Total	511,855	5,511	5,541	5,603	1,218	71

*Colorado Agricultural Statistics, 1935.

Plains Dry-Land

The altitude of the Plains Dry-Land district is slightly less than

Figure 11. A typical field in the Plains Dry-Land district; note the spacing and the level cultivation.

5,000 feet. Drought has nearly wiped out potato growing in this area during the last few years. Crop failures were almost complete in 1931, 1932, 1934, 1936, and 1937. Potato production in this area should be based on a program of summer fallow, since recent work in Nebraska shows that the potato crop largely depends on the amount of moisture stored in the soil at planting time. The amount of rainfall received during the growing season seldom has any effect on the proportions of the crop. A typical field in this area is shown in figure 11. Other difficulties experienced in this district besides drought are occasioned by grasshoppers, blister beetles, jack rabbits, and the Colorado potato beetle. In the western counties psyllid yellows, haywire, and flea beetles have also been prevalent. The future outlook for this district is quite dubious. Acreage at the present time is only one-fourth that of 1929, as shown in table 10.

TABLE 10.—*Census figures for the potato industry in the Plains Dry-Land district.*

County	Production 1929	Acreage 1934	Acreage 1929	Acreage 1919	Number farms reporting potatoes, 1929	Average yield to acre 1923-32*
	Bushels	*Acres*	*Acres*	*Acres*	*Farms*	*Bushels*
Yuma	36,637	171	577	430	678	59
El Paso	32,429	363	524	2,792	268	49
Elbert	26,972	56	509	2,454	466	49
Washington	26,283	76	397	485	445	58
Kit Carson	18,106	20	502	746	364	47
Lincoln	16,152	45	306	1,397	311	47
Phillips	12,541	94	203	138	318	58
Douglas	11,526	59	196	277	115	52
Total	180,646	884	3,214	8,719	2,965	53

*Colorado Agricultural Statistics, 1935.

Climate and Soil

Climate, soil, and availability of a good market determine the importance of potato production in any location. The climate must be favorable, so that large yields can be obtained in order to reduce the cost of production. The soil must be of such a nature that tubers of excellent appearance are produced, and a market must be available to absorb the production of the area. Cool weather during the growing season is necessary for successful production of potatoes. This fact confines main-crop production to the northern states and to high altitudes. Early crops are produced in warmer sections by planting early and harvesting before hot weather arrives. Although all other surplus-producing potato states lie north of Colorado, mean temperatures are very similar because of Colorado's high altitude. Potatoes are grown in this state at altitudes ranging from 4,000 to

10,000 feet above sea level. The normal mean temperatures of the main growing sections in Colorado, compared with those of Aroostook County, Maine, the largest potato-producing county in the United States, are shown in table 11.

TABLE 11.—*Mean temperatures by months during growing period (°F.).**

Place	County	April	May	June	July	Aug.	Sept.
Garnett	Alamosa	...	49.2	58.6	62.6	61.2	54.5
Greeley	Weld	...	56.8	66.6	70.9	70.0	61.2
Montrose	Montrose	...	57.6	65.2	70.6	68.4	61.0
Glenwood Springs	Garfield	...	52.6	60.6	65.6	65.0	57.9
Presque Isle, Me.	Aroostook	...	50.6	58.5	65.9	63.7	54.1
Early districts:							
Fruita	Mesa	50.0	58.4	68.1	74.2	...	...
Delta	Delta	40.5	59.0	68.0	74.0	...	...
Fort Morgan	Morgan	46.7	56.4	66.6	73.1	...	...

*Colorado Yearbook, 1932.

Temperature has a marked influence on vine and tuber development. The optimum temperature for best yields is about 64° F. At this temperature the plants are sturdy, with short internodes. The foliage is dense, with large, broad leaflets. Plants blossom quite freely, and the blossoms retain their color without fading. The tuber color is deep; the tubers are short, blocky, and generally smooth. Stolons are seldom branched and are usually quite short, always ending in tubers. At higher temperatures the vines are weaker, with longer internodes. The foliage is more open, with smaller, narrow leaflets. Plants do not blossom freely, and the blossoms fade in color. The lilac-colored blossoms of Irish Cobbler become white. The tuber color is lighter than at low temperatures, and the tubers are long and somewhat rough. The stolons are usually branched, frequently very long, and often emerge from the ground as leafy shoots instead of ending in tubers. The undesirable influence of high temperatures can be overcome to some extent by adjusting the dates of planting so that tuber formation will occur during a cool part of the season, either early or late. Effects of high temperatures can be further combated by cultivation, by irrigation, and by close planting so that the vines will shade the ground by the time tubers are forming. In some states straw mulches have produced large increases in yields.

As previously mentioned, very few potatoes are grown in the southeastern part of Colorado, including the entire Arkansas Valley below Canon City. This section is characterized by high temperatures, low rainfall, and generally heavy soils.

The unusual amount of sunshine makes Colorado growing conditions different from those of most other potato states. Skies are

cloudy only an average of 61 days a year, partly cloudy 153 days, and clear 151 days. This high amount of sunshine would tend to make the days unusually warm if it were not for the rarefied, dry atmosphere. The nights are always cool.

Rainfall is of vital importance on only 18 percent of Colorado's potato acreage. The mean annual precipitation in these sections varies from 14 inches to as high as 34 inches in some of the mountain sections. With proper handling, yields from 100 bushels to 400 bushels per acre are obtained in these sections.

The subsoil is of more importance than the surface soil. The

Figure 12. Field of Irish Cobblers, near Durango; the ideal cool growing season is indicated by large, vigorous plants with large, broad leaves and blossoms that do not fade in color.

important fact is that the subsoil must be porous so that the soil will be well drained. Potatoes are successfully grown on all types of soil, from almost pure sands and gravels to heavy brown, gray, or black clay loams, some of which are practically adobe in nature. The sandy loams, however, produce the largest crops and the best-appearing potatoes; they are more easily handled in preparation, cultivation, irrigation, and harvesting. The heavier soils are more expensive to prepare, are likely to puddle on irrigation, and may produce misshapen and poorly finished tubers; they tend to harbor more insects and diseases and present harvesting difficulties that include the bruising of tubers. If present trends continue, these soils will have to be abandoned for potato production or their structure so modified by the incorporation of coarse organic matter that they will produce potatoes of better appearance. The mountain

mesas, mountain parks, and benchlands above streams usually provide ideal conditions for potatoes. The river bottoms proper are usually poor because of insufficient drainage and often because of the presence of adobe soils.

Although the type of soil may be ideally suited to potatoes, there are few soils sufficiently supplied with organic matter to produce maximum crops. Colorado is an arid state and, with the exception of a few mountain districts, the native vegetation was, and still is, very scant. As a result even the new soil has very little organic matter. Maximum yields of potatoes cannot be produced until organic matter is supplied in some form by the grower. Even though a grower may not have the ideal sandy loam soil, he can benefit his soil materially by adding sufficient organic matter. The water-holding capacity of the sandy and gravelly loams will be greatly increased by organic matter, and the silt and clay loams will be rendered looser and more friable. They also will not crust, bake, nor crack so badly; and they will take water more readily and handle more easily. A soil is deficient if it contains less than 2 percent organic matter.

With the exception of a few high-altitude soils, Colorado potato soils are alkaline in reaction. The pH runs from 5.5 to 8.8. Alkali is not a factor in production, with the possible exception of a few places. Green manuring will not only add organic matter but will correct a slight tendency toward too much alkali, if the drainage is good. Yellow sweetclover has been very successfully used to improve land that was too highly alkaline.

Even after 50 years of potato production, much land is still planted to potatoes which is not suited to the crop. New sections are constantly developing, and old sections are shrinking or expanding, depending on prices the previous season. The average potato yield in Colorado is below those of Idaho and Maine largely because of this condition, and not because of the 18 percent non-irrigated acreage. After a favorable season for prices, potatoes are planted on heavy lands poorly suited to the crop, on lands on the edges of the irrigated districts where the water supply is uncertain and the soil low in fertility, or in non-irrigated sections where the rainfall is uncertain. The new growers have had little experience with the crop, and the seed used is usually of the poorest quality obtainable. This condition always results in large abandonment of acreage for the succeeding 2 or 3 years, with material damage to the average yield for the state.

Soil Fertility

Soil fertility has not been of much concern to the Colorado potato grower up to the present time. Very little of the land has been under cultivation more than 70 years, and the soil has not been intensively cultivated and drawn on heavily by large yields until

the past 25 years. Some soils are beginning to show the effects of abuse by reductions in yield; by producing plants which, by their color, show the deficiency of some plant food element; by the poor shape and appearance of the tubers produced; and by the difficulty with which they are worked and the ease with which they puddle and adhere to the tubers. These conditions emphasize the fact that the fertility of Colorado soils is not inexhaustible and that the following of a definite rotation and the use of proper fertilizers is more important today than ever before.

Rotation

A definite rotation should be adopted on every farm. A rotation reduces the tendency to fluctuate greatly the acreage planted to any one crop. It tends to stabilize the income, as all the crops and livestock are seldom unprofitable in any one year. Soil fertility will not only be maintained but in many cases increased. Scab, rhizoctonia, fusarium, and blackleg are soil-borne diseases which can be kept at a minimum only if potatoes are not grown on the same ground oftener than once in 5 years. Infestations by certain insects, such as flea beetle, wireworm, white grub, and seed-corn maggot, that attack potatoes are checked by a proper rotation of crops.

A tendency for farmers to specialize in potato production and to exclude other crops and livestock from their farms has never been carried so far in Colorado as it has in the eastern states. But the specialization tendency has been carried too far in some sections, at the expense of the soil and of yield and quality in the potato crop. In no case should more than one-fifth of the farmer's acreage be devoted to potatoes, and much better results will be obtained if this is reduced to one-eighth. The past few years have demonstrated the impossibility of depending on potatoes alone as a source of income in Colorado. Prices to growers have fluctuated from 30 cents a hundredweight to $4. Every potato farm should have enough livestock to consume the feed crops necessary in the rotation. This livestock will supply the manure necessary for maximum crops of potatoes.

As previously mentioned, most Colorado soils are lacking in organic matter, or humus. This lack can be made up only by use of a proper rotation in which alfalfa or sweetclover is plowed under and manure is added. The large majority of high yields are obtained following alfalfa. The Greeley district has maintained profitable yields over a period of 60 years, with alfalfa as the basis of a good rotation and the use of barnyard manure. The Montrose and Carbondale districts have similarly maintained yields, and the Montrose district has more members of the Colorado 600-Bushel Club than has any other district. From actual tests by the Colorado Experiment Station, fully 85 percent of the soils of the San Luis Valley are extremely low in organic matter. Much more green manure

must be plowed under and large quantities of barnyard manure applied over a period of years to correct this condition. If certified seed is planted and enough organic matter added to the soil, the average yield for the state could be increased to equal that of Idaho.

The value of rotation, manure, and alfalfa in potato production under western irrigated conditions is clearly shown by results obtained at two United States Department of Agriculture field stations at Scottsbluff, Nebr., and Huntley, Mont. The yields from the various rotations are shown in table 12. Manure was applied only once during the rotation, at the rate of 12 tons to the acre. The rotations in which manure was applied did not produce as high yields as did the same rotations with alfalfa added. The rotations

Figure 13. Alfalfa in the rotation is the foundation of profitable potato production.

including alfalfa, of course, are longer than the comparable ones without alfalfa. It will be noted from this table that only in rotations including alfalfa and manure can yields above 300 bushels per acre be maintained. In the Nebraska work manure had a value of from $2.32 to $4.62 a ton in terms of increased yields of potatoes. At Huntley 3 years of alfalfa in the rotation was considerably superior to 2 years in producing high yields of potatoes. Sweetclover has been used frequently as a soil-improving crop, and fortunately there is a rotation at the Scottsbluff station that includes sweetclover and potatoes. This rotation, with 10-year average yields, is as follows: (1) oats seeded to sweetclover, 59 bushels; (2) sweetclover pastured by sheep; (3) potatoes, 348 bushels; (4) sugar beets, 15.8 tons.

This rotation furnishes some information to San Luis Valley growers who pasture sweetclover with sheep as a preparation for potatoes. Unfortunately, there is no information available on the

TABLE 12.—*Beneficial effects of rotation, alfalfa, and manure on yields of potatoes.*

Rotation	Length of rotation	Scottsbluff, Nebr., U. S. D. A. Field Station*				Huntley, Mont., U. S. D. A. Field Station†			
		25-year mean yields	Increase due to manure	Increase due to alfalfa	Increase due to alfalfa and manure	24-year mean yields	Increase due to manure	Increase due to alfalfa	Increase due to alfalfa and manure
	Years	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Potatoes, beets	2	147	...	...	...	187	...	...	...
Potatoes, beets, manure	2	236	89	...	...	233	46	...	...
Potatoes, beets, alfalfa (2 yrs.)	4	280	...	133	...	260	...	73	...
Potatoes, oats	2	151	...	...	...	173	...	...	...
Potatoes, oats, manure	2	241	90	...	...	304	131	...	...
Potatoes, oats, alfalfa (2 yrs.)	4	266	...	115	...	195	...	22	...
Potatoes, beets, oats	3	182	...	...	...	169	...	...	...
Potatoes, beets, oats, manure	3	254	72	...	...	171	2	...	...
Potatoes, beets, oats, alfalfa (3 yrs.)	6	289	...	107	...	286	...	117	...
Potatoes, beets, oats-manure-alfalfa (3 yrs.)	6	311	22‡	...	129	310	24†	...	141
Average	..	...	84	118	129	...	60	71	141

*Lionel Harris, 1937, "Crop Rotation Work at the Scottsbluff Field Station," *Nebr. Potato Improvement Assn., Ann. Rpt.* 1936-37, pp. 5-12.

†Stephen H. Hastings and Dan Hansen, 1937 *Irrigated Crop Rotations at the Huntley (Mont.) Field Station 1912-35* U. S. D. A. Tech. Bul. 571.

‡Not included in average.

separate effects of the sweetclover in the rotation and the effect of the manure dropped by the sheep in pasturing the clover. The conclusions from practically a quarter-century of work on rotations at these two field stations are that alfalfa increases the yield of potatoes more than manure, but that the reverse is true of sugar beets, and that the sweetclover rotation promises to be one of the best.

Some growers have used rye as a soil-improving crop, and some work along that line has been done at the Huntley Field Station. Rye has been used in a 2-year rotation consisting of potatoes and oats, with rye seeded after the oats are harvested and plowed under

Figure 14. Humus, humus, and more humus; an excellent job of plowing under sweetclover.

the following spring before potatoes are planted. The 24-year mean yield of potatoes is only 93 bushels, which is the lowest yield from any of the rotations at this station; even the plot planted to potatoes for 24 successive years averaged 131 bushels. From this scant information, rye is hardly to be recommended.

Crop rotation may affect the quality as well as the yield of potatoes. Scab and rhizoctonia have been more prevalent in the short rotations than in the long ones at these two field stations. At Huntley the potatoes from the various rotations have been graded for the past 23 years. The manured rotations have produced an average of 7 percent more marketable potatoes than the same rotations without manure, and the alfalfa rotations have produced an average of 10 percent more marketable potatoes than those without alfalfa.

That the friability, looseness, or amount of air in the soil may materially affect potato yields has been recently demonstrated by

the Ohio Experiment Station. On silt loams or heavier types of soil, aeration of the soil by tile or sand increased yields from 39 to 70 bushels per acre, depending on the effectiveness of the aeration. Such methods are not practical, of course, but the same results were obtained by using corn as a green-manure crop. Chopped corn stover, thoroughly mixed with the soil by disking before plowing, greatly increased the yields on heavy soils. Nine tons of chopped stover to the acre increased the yield 43 bushels to the acre, and 18 tons of chopped stover increased the yield 109 bushels to the acre.

Fertilizers

The foregoing discussion has brought out the facts that alfalfa and sweetclover in planned crop rotations maintain excellent yields of potatoes, and that barnyard manure is an excellent fertilizer for potatoes. A summary of 9 years' work on commercial fertilizers in Utah resulted in the following conclusions: (1) "Manure is the only effective fertilizer for potatoes;" (2) "Manure increases the organic content of the soil by approximately 0.25 percent."

Preliminary tests of commercial fertilizers by the Colorado Experiment Station indicate that *no increases in yield may be expected where recommended practices regarding alfalfa or sweetclover and manure have been followed.* Wherever recommended practices have not been followed, commercial fertilizers have produced some increases in yield. Ammoniated phospate (10-53-0), at the rate of 100 to 150 pounds to the acre, has been the best commercial fertilizer used to date. Treble superphosphate and complete (4-12-4) fertilizer have increased the yield in one test, depressed the yield in one test, and shown no differences in five tests. Muriate of potash has produced no significant differences in total yield. Ammonium sulfate at the rate of 430 pounds per acre has increased the yield in one test, depressed the yield in three tests, and showed no significant differences in three tests.

Tests made in the three chief commercial potato districts show that, where rotations have been managed according to recommendations, commercial fertilizers will not only fail to increase yields but may actually damage the crop. On the Western Slope tests have been made during the past 2 years in Eagle, Garfield, and Montrose Counties. Ammoniated phosphate is the only material to produce a significant increase in yield—and this in only one of the five tests made in this district. Significant decreases have been obtained with ammonium sulfate, ammoniated phosphate, treble superphosphate, complete (4-12-4) fertilizer, and muriate of potash. All the tests were on alfalfa sod which had been manured at least once during the rotation. In Weld County ammoniated phosphate increased the yield on alfalfa sod land, but ammonium sulfate decreased the yield. On pasture lands, however, yields were increased by ammonium sulfate, treble superphosphate, or complete (4-12-4) fertilizer. Two

tests in the San Luis Valley indicate that most of the soils used for potatoes are deficient in nitrogen, and also that they may respond to phosphorus and potassium. Large increases in yield have been obtained with ammoniated phosphate (10-53-0) at the rate of 160 pounds per acre, or with complete (4-12-4) fertilizer at the rate of 700 pounds per acre. More alfalfa, sweetclover, and manure will have to be used in this district, or commercial fertilizers will become necessary to maintain yields. Green manure crops are necessary to maintain a satisfactory friability of the soil, even when commercial fertilizers are used to supply plant food; so growers should adopt the cheaper rotation methods now.

Figure 15. Pasturing sweetclover by the farm flock of sheep is excellent preparation for large yields of potatoes.

These preliminary tests indicate that commercial fertilizers have a marked effect on the grade of the crop produced and also on the shape of the tubers. This aspect of the use of commercial fertilizers may be more important to Colorado potato growers than the effect on yield. From four tests in which potatoes were graded, phosphate, complete, and potash increase the yield of U. S. No. 1's, while ammoniated phosphate and nitrogen decrease the yield of U. S. No. 1's. All the work on the effect of commercial fertilizers on tuber shape in Colorado has been done on the Russet Burbank, but reports from Montana, Maine, and New Jersey show similar results with other varieties.

Potash has the greatest effect on tuber shape of any of the fertilizers used in Colorado. This material produces short, wide, and thick tubers which are blunt on the ends. It produces "slick"-skinned tubers and completely removes the netting from Russet Burbanks. Phosphate produces tubers of the best general appear-

ance and the best handling qualities. It produces a heavy netting on the Russet Burbanks; the tubers are blunt, well-shaped, and more mature than tubers from other treatment plots. A heavy application of phosphate, plus a light application of potash, produced the best Russet Burbanks at the Mountain Substation in 1937.

Complete (4-12-4) fertilizer has little effect on tuber shape. Nitrogen and ammoniated phosphate have produced the poorest shaped Russet Burbanks. Nitrogen also removes the netting, and the "slick" Russet Burbanks produced in these plots are usually scabby. Ammoniated phosphate produces a heavier net than the untreated plots.

Figure 16. A case of nitrogen deficiency in the San Luis Valley; note the greener vines and the more vigorous growth next to the ditch. More alfalfa and more manure must be used on these farms, or expensive and less satisfactory commercial fertilizers will become necessary.

Since the commercial fertilizers used on the potato crop in Maine constitute 37 percent of the cost of production, Colorado growers should postpone their use as long as possible.

Suggested Rotations

The following rotations are suggested as a means of maintaining high yields of high-quality potatoes under Colorado conditions:

(1) Oats (barley, or barley and peas, or oats and peas) seeded to sweetclover; (2) sweetclover pastured; (3) potatoes; (4) sugar beets manured (vegetables or small grain). One field should be in alfalfa and left until the stand becomes poor, when it should be brought into the rotation with potatoes and a new field seeded to alfalfa with a nurse crop. It is advisable to seed bromegrass with alfalfa to reduce bloat and maintain yields over a longer period.

(1) Alfalfa; (2) alfalfa; (3) alfalfa (spring manured and last cutting plowed under); (4) potatoes; (5) sugar beets manured

(onions or corn); (6) small grain (seeded to alfalfa and bromegrass).

(1) Alfalfa; (2) alfalfa; (3) alfalfa; (4) alfalfa (spring manured and last cutting plowed under; (5) potatoes; (6) pod peas (sugar beets manured); (7) vegetables (corn); (8) small grain (small grain and peas) seeded to alfalfa and bromegrass.

(1) Alfalfa; (2) alfalfa; (3) alfalfa (spring manured); (4) potatoes; (5) grain (peas) seeded to sweetclover; (6) sweetclover pastured; (7) potatoes; (8) grain (peas or grain and peas) seeded to alfalfa and bromegrass.

These rotations will by no means satisfy all potato growers in Colorado, but they may be readily adjusted to fit the crops grown

Figure 17. Barnyard manure is the best fertilizer for potatoes.

and the conditions of the individual farm. The important points are that the potato crop follow either alfalfa or sweetclover, that the rotation be sufficiently long to control potato diseases, and that manure be applied to the land.

Soil Preparation

Potatoes, more than all other crops, need a deep, mellow seedbed for their best development. The soil should be plowed as deeply as possible. With power equipment, growers in the San Luis Valley plow as deep as 14 inches, although the average depth in most sections is from 8 to 10 inches. The chisel makes it possible to loosen the soil to a depth of from 16 to 24 inches.

Fall plowing is recommended, except in cases where the soil is light and likely to blow or pack badly during the winter. Except in regions of light snowfall where clods are not broken up by freezing and thawing during the winter, the land should be left rough

to catch and hold as much snow as possible. The ground should be worked down as early in the spring as possible so as to retain this moisture, as no amount of future irrigation or rain can take its place. There should be enough moisture in the soil at planting time to bring up the crop. Irrigating potatoes up is very risky, as poor stands are often the result. The ground should be irrigated before planting if there is not enough moisture to bring up the crop.

The preparation of alfalfa ground for potatoes is most difficult, as more power is required to plow such ground, and it must be properly and thoroughly done to kill the alfalfa. Several systems are used, depending on the type of soil and the locality. The surest method of killing alfalfa is to "crown" it (plowing shallow, so as to just cut off the crowns) early in the fall or late in the summer. The ground is then replowed to the proper depth late in the fall or the next spring. Little trouble with volunteer alfalfa has been experienced at the Mountain Substation, where crowning has been abandoned and the last cutting of alfalfa is plowed under deeply about the middle of August, while the alfalfa is still growing. This latter practice has also cut the cost of production. In plowing under alfalfa, sweetclover, or peas, it may be necessary to drag a chain from the plow beam to crush the plants down so they will be covered.

The general practice is to double-disk the ground early in the spring or immediately after plowing, if the ground is spring-plowed. The disk-harrow is not the most desirable implement for this purpose, as it has a tendency to pack the ground. The most satisfactory implement yet found is a small orchard chisel or an old alfalfa reno-

Figure 18. A potato planter equipped with a commercial fertilizer attachment. Commercial fertilizer gives best results when placed in bands a little below and to each side of the seed piece.

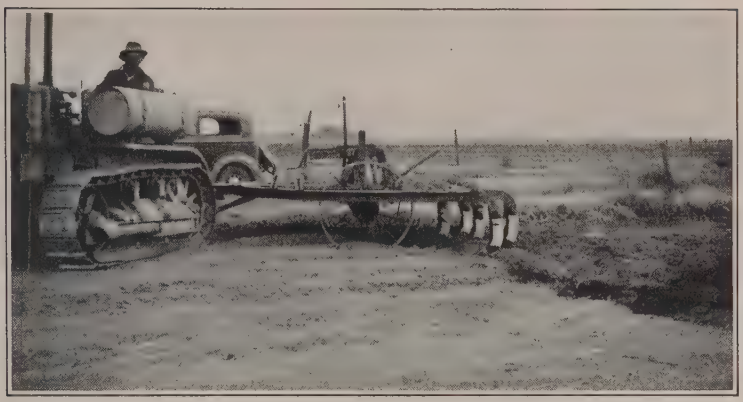


Figure 19. A six-point chisel breaking ground to a depth of from 18 to 24 inches.

vator with half the teeth removed. These implements loosen the soil from the bottom and leave it in excellent condition.

The finishing touches are put on the field with the spike-tooth harrow and the drag or leveler. This last implement removes all ridges and depressions and leaves the field absolutely level and in excellent condition for irrigation. *It is important to remember that no amount of future cultivation can make up for a poorly or carelessly prepared seedbed.*

Varieties for Colorado

Colorado has at present eight standard varieties of potatoes. At first thought this seems to be a large number; but when the wide variations in soil types, altitude, and climate are considered, the number is not surprising. No one district grows more than four of these varieties. Practically all sections of the state have now entered commercial production and have been forced to abandon old local-market varieties and to adopt one or more of the standard sorts.

Radical changes have taken place in the varieties grown during the past 25 years. Twenty-five years ago the Pearl was the standard variety for the entire state. Its roughness and susceptibility to disease have caused it to lose popularity, until today it is extremely difficult to find. Peoples Russet and Early Ohio are no longer recommended, and Brown Beauty is declining in popularity. No one will find it profitable to grow a variety not standard for his district, except in those rare cases where the grower has some special market. Trials by the Colorado Experiment Station and the experience of growers have determined the best varieties for the different districts.

There is now more potato-breeding work going on in the United

States than ever before. Several new varieties have already been introduced, and more are sure to follow. These varieties are being tested by the Colorado Experiment Station as they are introduced; in cases where a definite superiority to standard varieties is shown, they are being released to growers for further trial.

Red McClure (Perfect Peachblow)

The Red McClure is the most important potato variety grown in Colorado. It is estimated that 30,000 acres of this variety are planted in the state. It is the leading variety in the San Luis Valley and is also grown to a limited extent in some of the other mountain dis-

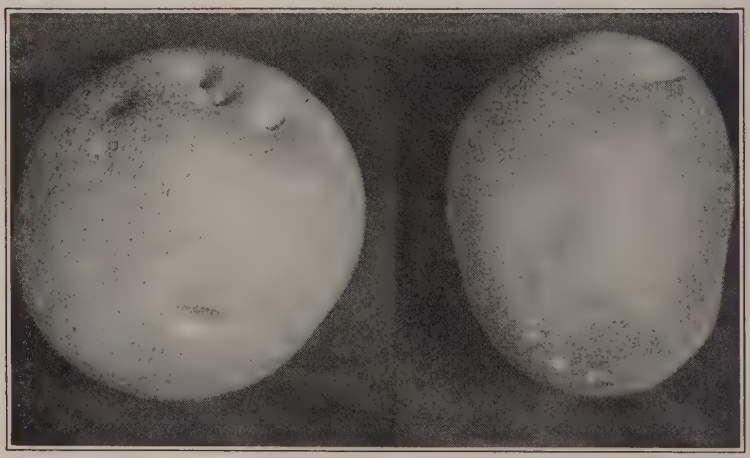


Figure 20. The Red McClure or Peachblow is the leading potato variety in Colorado.

tricts. It succeeds best at altitudes above 6,000 feet. Failures have been frequent at lower altitudes. It is an excellent variety for mountain dry-land areas. This variety has brought the highest price of any variety in the United States on the Chicago market for the past 5 years. Highly colored tubers bring a better price than the paler colored types.

The vines of the Red McClure are very strong and upright. Blossoms are plentiful and pink in color. The tubers are spherical and red, and the variety is late in maturing. In sandy soils the skin is netted or flaked, while in heavier soils the skin is smooth. The eyes are very few in number and shallow. This variety is very high in starch and has excellent quality. Three strains have been recognized in the state: the first, a dark-red or magenta-colored strain; the second, a pink strain with dark-red eyes; and the third, a white strain with red eyes. This variety has the best keeping qualities of

any variety tested in the state. The tuber set is heavy, and yields as high as 900 bushels to the acre have been recorded.

The variety has several disadvantages, including a susceptibility to scab, growth-crack, blackleg, mosaic, spindle tuber, pinto, heart leaf, and hollow heart. Most of these disadvantages can be overcome by planting certified seed and by regulating the planting distances and the irrigation practices. The tuber color seems to fade in some types of soil, and white streaks appear on the dark-red tubers.

Smooth Rural

There are about 14,500 acres of the Smooth Rural variety planted in the state at the present time. The acreage is decreasing because

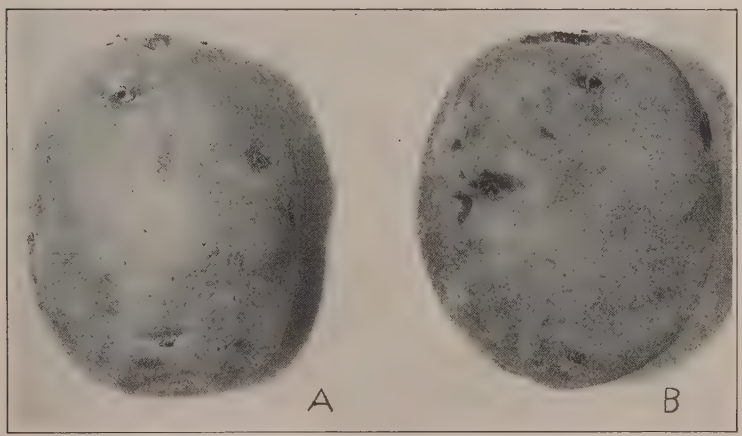


Figure 21. The Rural, either russet or smooth, is the hardiest of the late varieties.

of the better yields and quality obtained from the Katahdin and Chippewa varieties. Triumph has also replaced some of the Smooth Rural acreage. This variety is grown chiefly in northern Colorado and on the Western Slope, particularly in Montrose County. It succeeds wherever potatoes are grown, except that it is not recommended in dry-land areas where the annual precipitation is below 18 inches. It succeeds on heavy soils and in warm growing districts. It seems to be more resistant to scab than are Red McClure and Triumph, and it is also quite resistant to mosaic. The vine is strong and upright, with very little foliage early in the growing season. Later in the season, however, the vines branch and spread out. The blossoms are purple, with white tips. The tubers are short, oval, flattened, and pale-yellow in color. The variety is late maturing, and the sprout tips are purple. The skin texture depends on the soil type. On some soils the skin is very smooth, while on others

it is somewhat netted or flaked. The Smooth Rural is of good quality, if properly grown. A number of different strains are now recognized, among which are the Pioneer, Heavyweight, Number 9, and Mason. Smooth Rural variety does not set so heavily as Red McClure, Brown Beauty, or Triumph, but yields as high as 800 bushels to the acre have been recorded.

The variety has several weaknesses. Under some conditions the tubers become oversized, rough, and hollow. This condition can be overcome by closer planting, better seed, and more careful irrigation. Because of its late maturity and the practice of planting late, the tubers are often skinned, bruised, and low in starch content. More careful handling and earlier planting will assist in overcoming these defects. The tubers of this variety as they appear in the markets of the state are usually poorly graded or not graded at all. The stock contains digger cuts, small-sized cull tubers, and off-shape tubers. This condition has given the variety a bad reputation. "Worm track" has also been a serious defect in the Rural variety which can be overcome by spraying. A brown discoloration is also commonly found in the flesh; this is caused by fusarium species. Seed should be changed oftener and a long rotation adopted to correct this condition. Spindle tuber and giant hill are also common defects which can be overcome by planting certified seed.

Russet Rural

The Russet Rural variety is identical in all respects to the Smooth Rural, except for a brown pigment and a russeting of the skin. It is estimated that about 6,000 acres are planted annually in Colorado. This variety is increasing in popularity in northern Colorado and on the Western Slope. It is nearly as scab resistant as the Russet Burbank and has a tougher skin than the Smooth Rural; it does not bruise and skin so readily as the Smooth Rural. The color of the skin depends on the soil in which it is produced. On heavy or dark-colored soils the tubers are usually dark-colored and unattractive in appearance. However, on the lighter soils the tubers are bright golden-colored and very attractive. This variety has practically all the defects of the Smooth Rural, and the same remedies apply.

Bliss Triumph

It is estimated that about 16,000 acres of Bliss Triumphs are planted in Colorado; it is the most widely grown of any variety. It is the leading dry-land variety and one of the leading varieties in the early districts. Bliss Triumph is grown as a main crop or as a storage variety. The variety succeeds in heavy soils and hot weather and is grown at elevations up to 10,000 feet. It yields as well as the best varieties, having produced as high as 400 bushels an acre on dry land and 1,069 bushels an acre under irrigation. This variety usually brings a higher price than white varieties. It is more tol-

erant of fusarium than the Irish Cobbler and should be planted on dry lands in place of Cobbler.

The tubers of Bliss Triumph are cubical, and red or magenta in color. The Triumph is early to medium in maturity, low in starch, and not of exceptional quality. It is good for frying but can hardly be recommended for baking. Five distinct strains, based on length of periods of maturity, are recognized in Colorado. These have been designated as early, medium early, medium, medium late, and late. A similar classification has been made in Nebraska, where strains have been designated by numbers. The early strains have shorter vines and few, if any, blossoms; tubers are fewer to the hill, paler in color, and smoother than in the later types. The earlier types

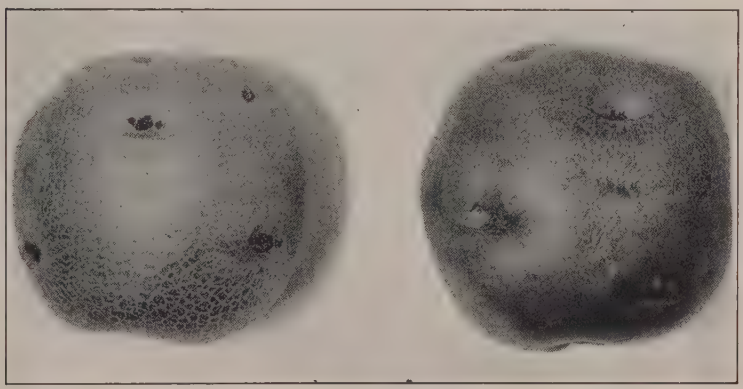


Figure 22. The Triumph can be grown in all parts of Colorado and is used either as an early or a late storage variety.

have not yielded so well under Colorado conditions as the later types. The blossoms are pale pink in color. The color and texture of the skin depend on soil type and temperature.

The Triumph is very susceptible to mosaic, spindle tuber, blackleg, scab, psyllid yellows, and haywire. It degenerates rapidly, and seed stocks must be renewed often under irrigated conditions. The most successful growers plant certified seed every year. This variety also air-cracks badly on digging and must be handled with extreme care in harvesting and storing. It does not keep so well in storage as the Irish Cobbler. Seed growers in the warmer growing districts must do their roguing early in the morning, since mosaic shows up best at this time. Tuber indexing and tuber-unit seed plots greatly assist growers in maintaining the Triumph variety.

Brown Beauty (Prolific)

The Brown Beauty variety in Colorado is grown exclusively in the San Luis Valley, since it requires cool growing conditions and

plenty of moisture because of its heavy tuber set. It is declining in popularity, however. Only about 10,000 acres of this variety are grown at the present time. It has produced the highest yield of any variety in the state, 1,145.17 bushels to the acre having been produced by L. G. Schutte of Monte Vista. The vines are strong and spreading, and under ideal conditions they attain a length of 6 feet. The blossoms are white and plentiful, if plants are checked in growth, but are almost absent if growing conditions are ideal. It is not so late as other late varieties. The tubers are oval in shape, moderately flattened, and usually netted or flaked; but they may be slick on heavier soils. The tubers have a faint pink color that is

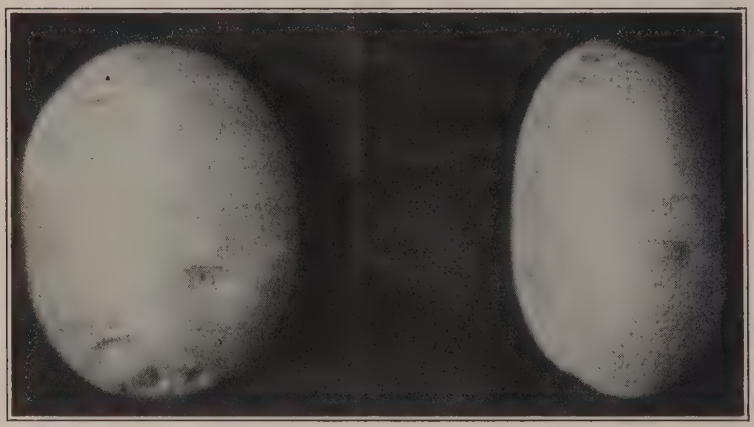


Figure 23. The Brown Beauty in Colorado is grown mainly in the San Luis Valley.

more intense at the eyes and gives the tubers a slight brownish cast. Purple-splotched mutations frequently occur.

The Brown Beauty has several rather serious defects. It is very susceptible to psyllid yellows, will not withstand an inadequate or uneven supply of moisture, and in general has not withstood unfavorable conditions so well as the Red McClure.

Irish Cobbler

It is estimated that about 8,000 acres of Irish Cobblers are grown in this state, mainly in the early districts in northern Colorado and on the Western Slope. Yields up to 600 bushels to the acre have been recorded. The Cobbler is more tolerant of psyllids than the Triumph and keeps better in storage. It is also quite resistant to mosaic. It is high in starch content, and its quality under various growing conditions varies less than that of other varieties.

The vine of the Irish Cobbler is medium in size, spreading, and strong. The blossoms are lilac in color, fading to white in hot

weather. The tubers are spherical, creamy white, and often rough, especially in heavy soils. The eyes are deep or shallow, depending on the soil type. The set is light, varying from three to eight tubers to the hill. Cobblers are early maturing.

The Irish Cobbler is susceptible to spindle tuber, fusarium, blackleg, and haywire. The best growers purchase new certified seed every year. This seed is produced in the mountain districts without irrigation. The Cobbler produced on heavy soils is rough, but some of this roughness may be overcome by more aeration and friability in the soils, attained through the plowing under of coarse organic matter. Two new varieties with smoother tubers than Cobblers have been introduced recently.

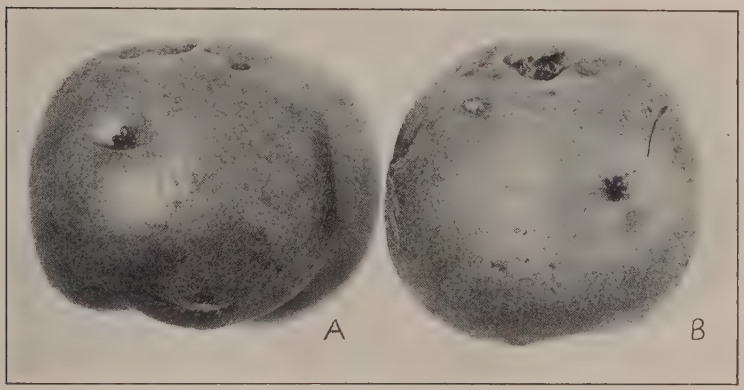


Figure 24. The Irish Cobbler is the leading early white potato variety.

Russet Burbank (Netted Gem, Idaho Russet)

It is estimated that about 5,000 acres of Russet Burbanks are grown annually in Colorado. This variety succeeds best on fertile soils and at altitudes of between 6,000 and 8,000 feet. It is grown mainly in Garfield, Eagle, and Pitkin Counties and in the river bottom of the San Luis Valley. It is very difficult to grow this variety to perfection. It will not tolerate heavy soil nor heat, and an uneven moisture supply results in knobby tubers. The chief market for this variety is in the larger cities of the Eastern Slope, including Denver, Colorado Springs, and Pueblo. The variety is grown on the red soils of the Western Slope. These red-soil Russets bring a 40- to 60-cent premium over common-soil Russets, and it is believed that the red-soil Russets are the highest priced potatoes in the United States. The Russet Burbank is more resistant to scab than any of our other varieties. Yields up to 600 bushels to the acre have been recorded.

The vine of the Russet Burbank is medium in size, seldom being more than 3 feet in height; the blossoms are white and moderately

profuse. The variety is medium late in maturity. The tubers are cylindrical in shape, with blunt ends and shallow eyes. The skin is thick and russeted. This potato keeps well. It is high in starch content. It is mealy and is famous for its baking qualities.

The most common defects found in the Colorado-grown Russet Burbanks are spindle tuber, mosaic, giant hill, and leaf roll. Seed stocks have not been renewed with sufficient frequency; it is recommended that certified seed be purchased about every 3 years. It has been found recently by the Colorado Experiment Station that "slick"

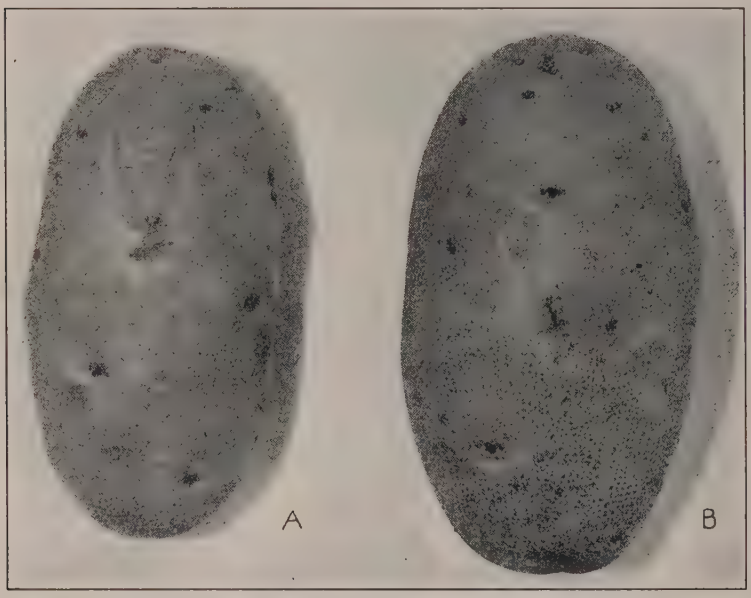


Figure 25. The Russet Burbank is regaining its popularity with growers; it is scab resistant and the most famous baking potato.

tubers in this variety are the result of an insufficient supply of phosphate. Pointed ends can be remedied by using good seed stock, by applying phosphate and potash fertilizer, and by planting late.

Results at the Mountain Substation indicate that the best planting date for high yields and best quality is between May 18 and May 25. At lower elevations a later planting date may be desirable. Knobs result from improper irrigation and from psyllids. Spraying should be more generally practiced. A common criticism of the Russet Burbank is that the tubers are too dirty. This objection can be overcome by getting more organic matter into the soils. It is recommended that bromegrass be seeded with alfalfa and that the Russet Burbank variety be planted on this sod. Only one crop of

potatoes should be included in the rotation. Washing or brushing may be necessary under some conditions. Rhizoctonia is another common defect which can be overcome by seed treatment and longer rotation.

Katahdin

The Katahdin is a new variety introduced by the United States Department of Agriculture and released to growers in Colorado in

Figure 26. The Katahdin has recently become a standard potato variety for the state; the upper tuber is Rural variety.

1934. It is estimated that there are now 3,000 acres of this variety grown in the state, mainly in the San Juan Basin, on the Western Slope, and in the Northern Colorado district. The Katahdin is an excellent dry-land potato and is increasing in popularity. It is resistant to mosaic and produces a high percentage of U. S. No. 1 potatoes. It has produced yields as high as 800 bushels to the acre. This variety holds its shape very well under all conditions.

The Katahdin vine is very strong and vigorous. It is dark-green in color, with very large leaflets. The blossoms are pink and numerous. Seed balls are commonly produced. Katahdin is late in maturing. The tubers are creamy white, short, oval to round, moderately flattened, and with a few shallow eyes. The tubers set early,

and in Michigan the Katahdin has outyielded Cobbler when the two varieties have been planted and dug on the same dates.

This variety is susceptible to spindle tuber and leaf roll. Under some conditions tubers have hollow heart and are oversized. Katahdin must be planted more closely together than Rural to overcome these defects. The tubers set shallow, and quite commonly they sunburn unless planted deeply. This variety is not so high in starch content as some other varieties, being only slightly above Triumph in that respect. It is an excellent variety, however, for frying and for potato chips and french fries.

Chippewa

Another new United States Department of Agriculture introduction is the Chippewa variety, which was released in Colorado in 1936. Its popularity is rapidly increasing, and it is preferred to Katahdin by some growers. It is higher in starch, with better cooking qualities and earlier than Katahdin. It has been reported to be only about a week later than Cobbler. There has been little commercial production of the variety as yet, but it is recommended for trial in both the early and late districts.

Other Promising Varieties

Other potato varieties which promise well for Colorado production include the following:

HOUMA is a promising United States Department of Agriculture introduction. The tubers are round and white; the variety is late in maturing and sets a large number of tubers.

SEBAGO is a United States Department of Agriculture introduction named in the spring of 1938. It is somewhat resistant to late blight. It has not yet been released in Colorado.

EARLAINE, another United States Department of Agriculture introduction, was named in the spring of 1938; it is an early, white, smooth-tubered variety. It has been very promising in tests and may possibly replace the Cobbler.

CS-110 is the outstanding variety so far produced at the Colorado Potato Experiment Station of the United States Department of Agriculture, located at Greeley. It is a late variety, with blue blossoms, and has performed well in test plots over the state.

WARBA is an early variety from the University of Minnesota. The tubers are white, with red eyes; there is also a red-tubered sport. The variety has several defects and will require more testing before it can be generally recommended.

MESABA is an early, white variety from the University of Minnesota, also introduced to replace the Cobbler. Further testing is necessary before any recommendations can be made.

Seed

The quality of seed planted is one of the most important factors in the production of profitable potato crops. Although all practices and other conditions may be ideal, maximum crops cannot be obtained unless the seed is of the best. Good seed is seed that is as free from disease as possible; it is free from variety mixtures; it comes from a high-yielding strain; it has been grown under favorable climatic conditions; and it is firm and sound, with sprouts first beginning to show at planting time.

It will be especially noted that no mention has been made of type nor of appearance in this description of good seed. Both of

Figure 27. Source-of-seed test in the San Luis Valley; similar tests are located in other important potato districts of Colorado. The better potato growers select their seed from these plots instead of from the bin.

these depend almost entirely upon the conditions under which the seed was grown. Altogether too much emphasis has been placed on type and appearance and too little emphasis on freedom from disease. The practice of selecting smooth, nice-appearing tubers from the bin has actually hastened the degeneration of such varieties as Russet Burbank, Red McClure, and Brown Beauty. The grower believed he was improving his seed, and that the expense of bin selection was thereby justified. Plants affected with leaf roll or mosaic produce tubers that are smooth and of ideal shape, and that have an excellent appearance in the bin but are not fit to use as seed. On the other hand, some tubers in the same bin may be knobby and of poor appearance but much better seed than the others, because it takes a vigorous plant to produce knobby tubers.

Planting tubers that are left after all marketable stock has been sold is altogether too common a practice. This practice always leads eventually to "running out" of the seed, but it is surprising how

long the process sometimes takes under the favorable soil and climatic conditions of this state. The period of favorable prices—1925, 1926, and 1927—completely ruined seed stock in practically all districts of the state, because growers sold everything but the poorest culls, which were used for seed. This seed stock was already well started toward degeneration by this practice following the high prices of 1919. Growers could not be brought to a realization of the diseased condition of this seed during the favorable growing seasons which prevailed through 1930. Many growers scoffed at the idea of good seed and cited instances of "hog feed" producing profitable crops which, unfortunately, was true in seasons such as 1930, 1935, and 1936.

While crops produced from such seed may be profitable in certain seasons, they are not the largest crops that could be produced; so the grower has suffered actual losses in reduced yields, although he may not realize it. In general, growers have little idea of what good seed is, and the so-called "hog feed" was probably the best seed in the bin. It consisted of the off-shape tubers and those that did not conform to the grower's often mistaken idea of type. He had selected for planting those tubers which were smooth, shallow-eyed, weak, and diseased. Actual experiments have proved that the good seed was in the "hog feed." The past season has shown the true value of all this so-called seed. Growing conditions have not been quite so favorable, and only the best seed produced profitable crops. In view of this condition, it is more than foolish for any grower to buy seed of which he does not know the disease record.

There is a common belief among growers that changing seed or getting seed grown on a different type of soil or under different climatic conditions will materially increase their yields. This is not always true, as certain diseases may be present in the different locations which are not present in the grower's own locality. Growers also have had the idea that they could have someone in another district grow a crop from some of their seed, bring it back, and from it in turn again produce a maximum crop. In some cases the yield was improved the first year by this method, but the seed was back to its former state in the second year. Many times no increase was obtained, even in the first year; and sometimes the seed was actually worse, depending upon the section to which it was sent for the change. The practice cannot be recommended.

The only cause known at present for degeneration in potatoes is disease. It is foolish to believe that growing diseased stock in any district of the state will eliminate, in one season and without any assistance from the grower, any diseases that may be present. Many seed stocks are so badly degenerated that even the best-known methods cannot make them productive. The only possible method of assuring good seed is to buy certified seed.

Certified Seed

Certified seed is seed which has been inspected twice in the field and once in the bin, and upon which a certificate has been issued by the Department of Horticulture of Colorado State College. Seed is also certified in other states by some one recognized authority.

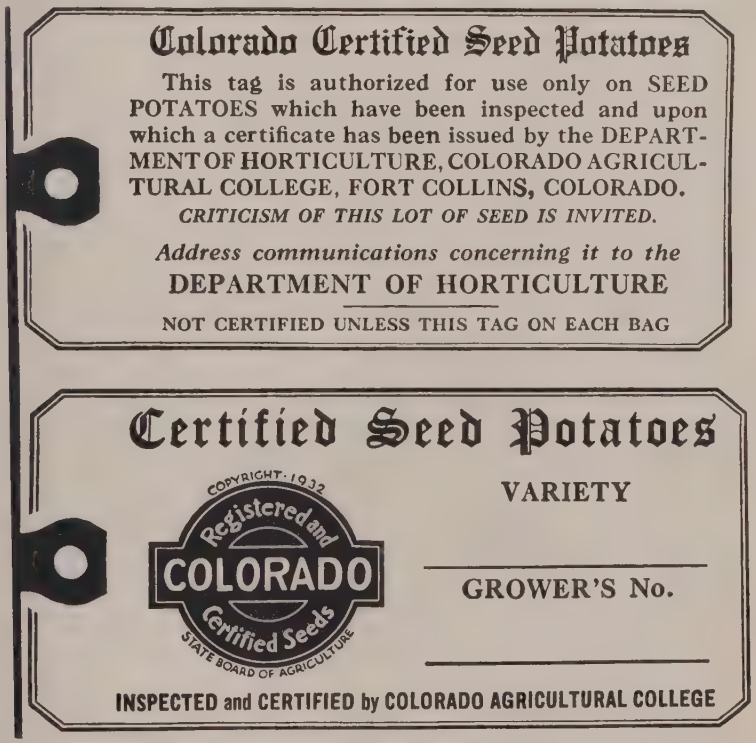

Colorado Certified Seed Potatoes
This tag is authorized for use only on SEED POTATOES which have been inspected and upon which a certificate has been issued by the DEPARTMENT OF HORTICULTURE, COLORADO AGRICULTURAL COLLEGE, FORT COLLINS, COLORADO.
CRITICISM OF THIS LOT OF SEED IS INVITED.
Address communications concerning it to the
DEPARTMENT OF HORTICULTURE
NOT CERTIFIED UNLESS THIS TAG ON EACH BAG
Certified Seed Potatoes
COPYRIGHT 1932
Registered and
COLORADO
Certified Seeds
STATE BOARD OF AGRICULTURE
VARIETY
GROWER'S No.
INSPECTED and CERTIFIED by COLORADO AGRICULTURAL COLLEGE

Figure 28. All seed certified in Colorado must have this blue tag on each sack.

The inspectors are men who have been trained to recognize potato diseases under all conditions. Certified seed always bears the tag issued by the certifying authority for lots of seed which meet the requirements for certification. It is the best seed that can be produced, using modern methods of selection. As previously mentioned, most potato diseases cannot be recognized in the tubers. For this reason the two field inspections are the most important for passing on seed stock.

The certified seed program in Colorado is designed primarily to make the best-quality seed available to Colorado potato growers

and to have it available as nearby as possible. Certified seed for the Greeley district is produced in the dry-land sections surrounding that district, within the district itself, and also in the mountains. Certified seed for the San Luis Valley is produced not only in the valley but also in various high-altitude districts in the state. Certified seed for the Carbondale district is produced at the higher altitudes in that district, and certified seed for the Montrose district is similarly produced.

The value of certified seed has been well demonstrated during the past few years. In 1932, 254 demonstrations under the supervision of county agents showed an average of 59.6 bushels to the

Figure 29. This 10-acre field of certified Irish Cobbler potatoes was planted in tuber units; it is isolated from any other potatoes by at least 15 miles and is at an altitude of 9,300 feet above sea level.

acre in favor of certified seed over common seed. This increase ranged from 10 bushels on dry land, where yields were generally low because of drought and insects, to 379 bushels in one test in the San Luis Valley.

In 1933 growers of certified seed had an average yield of 260 bushels an acre, which is 104 bushels above the state average. The percentage of certified seed grown on dry land was practically the same as that for the state, so the figures can be directly compared. Certified seed growers in Rio Grande County had an average yield of 322.4 bushels an acre compared with 177.3 bushels, the average for the entire county from 1928 through 1932. Conejos County certified growers averaged 291.7 bushels, while the average for the county was 155.3 bushels. In Alamosa County the certified growers averaged 316.7 bushels, and the county average was 159.2 bushels.

The Saguache County average was 163.3 bushels, while certified seed growers averaged 287.3 bushels. Yields of this type are possible in any of the irrigated districts, provided growers will plant only the best seed and use the best methods of production.

In addition to the field inspections, Colorado State College is constantly endeavoring to obtain the best strains of seed for certified seed growers. The tuber indexing of all the better strains in the state has been completed, and some stocks are indexed every year. Tuber indexing is the most efficient method yet devised for eliminating diseases from seed stock. In this method one eye is cut

Figure 30. Tuber-indexing foundation seed in the Colorado Experiment Station greenhouses at Fort Collins.

from a large tuber, the eye is planted in the college greenhouses during the winter months and given a number, and the tuber from which it is cut is given the same number and placed in storage. Temperatures can be well regulated in the greenhouses, so that many diseases if present will express themselves. When the plants are about 10 inches tall they are very carefully examined. The numbers of those which show disease or weakness are recorded. The stored tubers are then sorted, and those bearing the numbers of diseased or weak plants are discarded. Recently growers have sent the numbered seed pieces to the college in egg crates. The numbers of the tubers to be thrown away are sent to the grower after the plants are grown and the readings taken. All growers applying to the college for certification are required to send samples of their seed to the Mountain Substation for a test planting

in comparison with all other lots of certified seed. Disease records are taken on these plots, and they must meet the regular requirements here as well as in the growers' own fields.

In the early potato-growing districts, growers commonly purchase enough certified seed to plant a seed plot. This seed plot, planted in July, furnishes the seed for the main early planting the following year. While this is a desirable practice, many of the better growers have found it profitable to buy certified seed for their entire commercial acreage each year. Seed stocks of the late varieties in the main crop-producing sections do not have to be renewed this often, but it is recommended that growers of these varieties purchase at least enough seed for a seed plot every 2 to 5 years.

Seed Selection

Most growers in the state have conscientiously sorted over whatever stock they have on hand in the spring and thought they were obtaining some excellent seed if they discarded from 50 to 70 percent. This selection method is generally referred to as "bin selection." It has been mentioned previously that some of the diseases which do the most damage cannot be recognized in the bin. There have been many cases in this state where growers actually hastened the degeneration of their seed by picking smooth, shallow-eyed tubers. Many fields of Peachblows and Brown Beauties in the San Luis Valley contain as high as 95 percent wildings as a result of this practice. The amount of leaf roll in Russet Burbanks in the Carbondale district has been similarly increased.

It is recommended that growers who wish to maintain their own seed stocks learn the potato diseases in the field, and that they pull these diseased plants or rogue them during the growing season. If the roguing is properly done, it will not be necessary to sort the seed for planting at all, unless rot shows up in it. Profitable yields can be obtained for a much longer period by this method than by bin selection. Growers today would be wealthier by thousands of dollars if the money and time necessary for bin selection had been spent instead in roguing their fields during the growing season.

The most efficient method by which a grower can maintain his seed is the tuber-unit seed plot, and every certified seed grower is required to plant such a plot. In this method each tuber is cut separately into four pieces. These four pieces are planted in adjoining hills, a space is skipped, and four pieces from the next tuber are planted.

Some difficulty has been experienced in planting in this manner, but growers who have the regular two-man planters have obtained very satisfactory results. Two men are used on the rear of the planter instead of one man as in ordinary planting. The seed has been previously treated and cut partly through into quarters. The tubers are placed in picking baskets or lettuce crates, the quarters

of each tuber hanging together. The picking baskets are placed in the hopper of the planter; one man takes a tuber, breaks the four pieces apart, and places them in four partitions in the planter wheel. The other man reaches for a tuber, breaks it into four pieces, allows one partition on the planter wheel to go by, and places his four pieces in four adjoining partitions. The two men thus alternate in placing the units.

The advantage in this manner of planting comes in roguing. All diseased plants are grouped and not scattered over the field. Four diseased plants are more easily distinguished than a single plant.

Figure 31. Harvesting certified sample plots at the Mountain Substation.

In some cases only one or two plants of the four show the disease, but the rest probably have it also, and the entire unit should be removed. This condition explains why carefully rogued stock planted in the ordinary way sometimes shows disease the next year. Despite the most careful methods of selection, seed rarely is absolutely free from disease and rarely maintains this freedom for three or more seasons. Some seed growers harvest each unit separately and plant the tubers from each separately the following year, thus establishing tuber lines. Tuber lines are more uniform than field-run stock.

Most of the commercial growers who operate on a fairly large scale will find that it does not pay them to attempt to keep a seed plot. It must be isolated, it interferes with the rotation, the machinery must be dragged to two fields, and the grower does not have

time to rogue it properly. These growers will find it cheaper and more satisfactory to buy enough certified seed for their plantings. Satisfactory results will be obtained in most cases by getting certified seed every 2 to 5 years. Enough for the entire acreage need not be purchased, but only enough for a plot the increase from which will plant the entire acreage the following year.

Irrigated vs. Non-Irrigated Seed

Does irrigation water have any effect on the vigor and vitality of seed potatoes? This question has been the subject of many heated debates in the potato industry. At first thought, the subject seems

Figure 32. With proper care and handling, certified seed produces crops such as this one.

absurd. How could water running down a furrow affect seed any more than water falling as rain from above? Many experiments, however, in years past have seemed to prove that irrigated seed is inferior. The results in practically all cases, however, were based on yields of seed stocks of different origins and of an unknown virus-disease content. The knowledge of virus diseases was very meager when most of these experiments were run, so it is not surprising that they were not often mentioned in connection with results. The conviction that irrigated seed is inferior is so firmly entrenched that even today irrigated fields are barred from certification in some states. This has never been the case in Colorado, however.

The Idaho Experiment Station pointed out in 1920 that there was no difference between irrigated and non-irrigated seed when "good, healthy tubers true to variety were used."

W. C. Edmundson of the Colorado Potato Experiment Station at Greeley concludes:

> "The experimental results with the Rural New Yorker, the leading commercial variety of the Greeley (Colo.) district, indicate that irrigation water has little or no effect on the vigor and vitality of seed.
>
> "From 1921 to 1924, inclusive, irrigated seed grown under a varying number of light applications of irrigation water produced very similar yields.
>
> "From 1926 to 1929, inclusive, comparisons made of seed receiving different numbers of light irrigations, seed grown without irrigation, and seed grown in wet, seepy soil resulted in similar yields.
>
> "Seed grown for 15 years under irrigation produced yields comparable with non-irrigated seed."

Similar conclusions have recently been reached in Montana and Nebraska.

Any difference in the yielding ability of seed stocks is due mainly to diseases. Evidence is also accumulating that strains of superior yielding ability may arise as sports or mutations. Under dry-land conditions plants are farther apart; insect carriers of disease are not so numerous; and the harder growing conditions tend to eliminate weak and diseased plants, or they show up so plainly that they are more easily rogued. These facts explain the superiority of non-irrigated seed in earlier tests. Isolated seed plots planted in tuber units with occasional tuber indexing make it possible to produce just as good seed under irrigation as under dry-land conditions.

Whole vs. Cut Seed

Cut seed is planted in all sections of Colorado except the San Luis Valley. Growers in the valley have for years made a practice of saving the small tubers from their commercial crops for seed. As a result of this practice, many fields did not contain a single normal plant, and it is surprising that any yield at all was obtained. Many of these fields averaged from 75 to 100 sacks an acre, despite the disease, so growers were convinced that there was nothing wrong with the seed. Some growers are much too easily satisfied. No grower should stop trying to better his methods until he averages 200 sacks or more to the acre in any irrigated district in this state.

Many growers in the San Luis Valley are convinced that they cannot obtain stands from cut seed. In 1932 quite a number of seed plots were planted with cut seed in Saguache and Rio Grande Counties. In a great many of these seed plots, where the cut seed had been properly handled, there was no difference in stand between the whole and the cut seed. Cut seed should not be planted until the soil has warmed up. It should be planted immediately after cutting and should be treated with one of the organic mercury compounds for best results. It should not be planted so deeply as whole seed. The chief disadvantage in planting whole seed, as it is done in the

San Luis Valley, is that weak or diseased hills produce more small tubers than the strong, healthy hills. Over a period of time the strong, healthy hills would be eliminated, because in favorable seasons they produce no small tubers which will go through the screen. It must be admitted, however, that planting whole seed is cheaper than planting cut seed. Numerous experiments prove that whole seed produces better stands and higher yields than cut seed, provided both come from certified seed. If growers in the valley wish to continue this practice, they should purchase certified seed about every 2 years.

Figure 33. This hill of potatoes on the right was produced by the smooth, shallow-eyed potato so highly esteemed by the bin selector; the hill on the left is normal.

Keeping Seed Until Planting Time

In the definition of good seed previously given, it was said that good seed should show the first sprouts at planting time. In some sections it is extremely difficult to keep seed from sprouting before planting time arrives. Some growers in the higher altitudes have no difficulty in keeping Irish Cobblers without sprouting until nearly the first of July. Other growers have difficulty in keeping their seed after the first of April.

As long as the temperature of the storage can be held close to 40° F. and the tubers kept absolutely dry, sprouts will not develop to any appreciable extent. Moving the seed occasionally aids in keeping it dry and inhibits sprout formation at temperatures even above 40° F. Every effort should be made to preserve the first crop of sprouts, as numerous experiments have shown that even the removal of one crop of sprouts may reduce the yield. Some growers have found it profitable to cut ice and place it in the cellar to inhibit sprout development until planting time.

Another method of preserving the first crop of sprouts until planting time is green sprouting. As soon as any sprouts begin to

develop in the cellar the tubers are spread out in subdued light in a barn or shed where they will be protected from frost. They should not be placed in direct sunlight. Under these conditions sprouts will remain short, thick, and tough; and they are not easily broken off. This method may have serious disadvantages if the greening period is prolonged more than 2 or 3 weeks, as the sprouts may become so large that difficulty will be experienced in getting the pieces through the planter. The practice is profitable, however, as E. V. Hardenburg* of Cornell University, Ithaca, N. Y., obtained an average increase in yield over a 4-year period of 17.1 bushels an acre from green sprouting. The increase would undoubtedly have been greater had sprouts been removed from the ungreened seed. The varieties used were Rural and Green Mountain.

The practice of removing seed potatoes from cellars as soon as sprouts barely start to develop, and placing them in cold storage, is increasing, especially in the Greeley area. This is the most practical and successful method of retarding sprout development until planting time. H. O. Werner† of Nebraska has made a careful study of the storage of seed potatoes at Alliance. He found that placing seed in cold storage on April 1 resulted in an average of 12.6 percent more sound tubers over a 3-year period. An average increase of 18.5 bushels an acre in yield over a 5-year period on dry land was obtained from tubers put in cold storage on April 1. The largest increase was 45.7 bushels in 1930, when yields were comparable to yields under irrigation. He also found that a "warming up" period of 5 days increased yields over those from seed planted immediately on removal from cold storage. A 10-day "warming up" period did not give as good results as the 5-day period.

Potato Diseases

Growers commonly speak of potatoes "running out." This "running out" is caused mainly by potato diseases. Potato diseases are classified in two groups. The first, parasitic diseases, are those caused by a known fungus or bacterium that can be isolated and studied in artificial culture. The second group is composed of diseases known as the virus or degeneration diseases; these are the diseases that cause the "running out" of potatoes. No organism has yet been isolated in this group.

Parasitic diseases are blackleg, fusaria, rhizoctonia, scab, early blight, dry rot, and bacterial wilt. Virus diseases are mosaic, leaf roll, spindle tuber, witches broom, curly dwarf calico, unmottled curly dwarf, giant hill, yellow dwarf, and haywire. All these diseases are seed-borne, with the possible exception of early blight.

In addition to these diseases, a new class is coming to be recognized which is generally called "insect diseases." In this group be-

*E. V. HARDENBURG, *Green Sprouting Seed Potatoes* (New York, Cornell, 1935) Bul. 632.

†H. O. WERNER, *Cellar and Cold Storage of Sound and Mechanically Damaged Triumph Seed Potatoes* (1936) Nebr. Res. Bul. 88.

longs the hopperburn or tipburn, which is prevalent in the East but has not yet been observed to any extent in Colorado. In this group also belongs psyllid yellows, which has caused so much damage in this state.

The foregoing list of diseases may seem a large one, but it includes only a small part of the causes of potato "troubles." There are more than 90 diseases and other "troubles" of potatoes, and the purchase of certified seed is the principal way in which a grower can reduce losses from them to a minimum. Some of these diseases are carried in the soil, as well as on the seed. Blackleg, the wilts, rhizoctonia, and scab will live from year to year in the soil; and even though clean seed is planted, the resulting crop will become infected from the soil. For this reason a crop rotation is necessary to keep the soil from becoming too badly infected with these diseases.

Figure 34. Stem lesions of rhizoctonia on young plants; some plants have been girdled, causing missing hills or weak plants.

Parasitic Diseases

RHIZOCTONIA is one of the most common potato diseases in Colorado. It occurs in practically all districts of the state, causing moderate losses every year. On poorly drained soils and in cool, late springs the damage is more severe, amounting to total losses in some cases. Losses in stand caused by this disease are frequent, occurring at temperatures below 59°. It is a fungus and may attack the sprouts on the tuber before they get through the ground, rotting them off; the infection in this case comes from the soil or from the little, black specks on the skin of the seed tuber. The fungus thrives in cool weather—about 64° F. —and does not occur so frequently in the warm-

er growing districts where temperatures are above 70° F. After the first sprout is rotted off, new sprouts may form at the base of the old, and these may in turn be rotted off or produce weak plants. In case of later attacks, brown, scabby lesions appear on the underground stem or on stolons or roots.

Severe damage occurs only when these lesions girdle or completely surround the underground stem. In this case the starches and food materials manufactured by the leaves are cut off from the tubers. Many small tubers are formed at the ground line, above the lesion, to take care of the food which ordinarily goes to the tubers. Small, green, aerial tubers are also found in the axils of the leaves. The plant may become larger and the leaves stiffer in

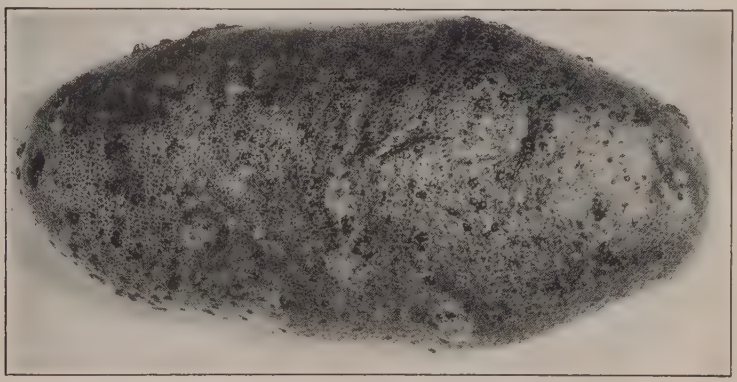


Figure 35. An extreme case of rhizoctonia sclerotia on the tuber; many growers mistake evidences of this disease for dirt.

appearance because of the accumulation of starch. Yellowish or reddish discolorations may also appear in the top of the plant.

In seasons when there is plenty of moisture toward the end of the growing season, the black specks that are the resting stage of the fungus (sclerotia) are not so noticeable. These black specks, however, become very large and detract considerably from the appearance of the tubers when the soil is dry toward the end of the growing season. The control for this disease is treating the seed every year and not planting potatoes on the same ground oftener than once in 5 years. Manure and alfalfa in the rotation also decrease the amount of this disease. Delaying planting until the ground is thoroughly warmed and covering the seed at only a shallow depth will also help greatly in controlling this disease.

COMMON SCAB is both seed- and soil-borne. It is favored by alkaline soil reactions, so it is very difficult to control once it becomes established in a Colorado soil. It seems to be worse in dry seasons than in those of a normal amount of moisture. Scab develops best

at temperatures above 70° F. Authorities are not agreed on just what conditions favor its development. Some maintain that a tight soil favors it; others claim that too much aeration favors it. This station is inclined to favor the packed-soil or lack-of-aeration theory, as scab seems to be worst in spots where there were old stockyards or where old straw butts have stood. It is admitted that the organic matter provided by the hay stacks or straw butts may have been responsible for development of scab. Fresh manure seems to favor its development; but potatoes have been observed growing in an old feedyard in almost pure manure which was well rotted, and there was not a sign of scab.

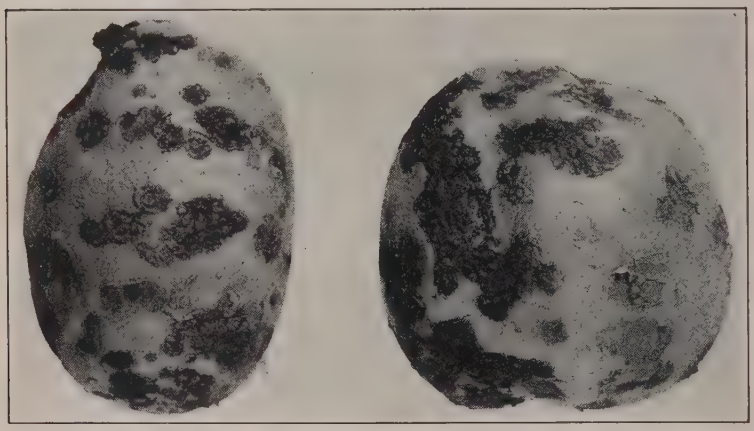


Figure 36. Common scab is best controlled by planting resistant varieties such as Russet Burbank and Russet Rural.

Scab on the seed is of very little importance, as it is quite easily killed by seed treatment. The main objective of the grower should be to prevent infection of his soil by treating his seed and by a long crop rotation. The only alternative after the soil has become infected is planting resistant varieties, of which there are very few at present. The Russet Burbank is the most resistant variety but is not suited to dry land. The Russet Rural is second; and the Rural New Yorker shows more resistance than the Peachblow, Triumph, or Cobbler. None of the early varieties shows any resistance. A long rotation in which potatoes follow alfalfa, never sugar beets, will also help.

BLACKLEG is bacterial instead of fungous in nature. It is favored by cool, moist growing conditions. The Peachblow, Triumph, and Cobbler varieties seem especially susceptible in this state. The disease starts with the rotting of the seed piece. This somewhat wet, slimy rot progresses up the underground stem, and in cool seasons it sometimes involves the entire plant above the ground. Most districts

have trouble with this disease only in the early part of the season, as the coming of warmer weather seems to check its progress.

Blackleg is especially bad in the San Luis Valley. Fields have been observed there in which fully 50 percent of the plants were severely infected. The appearance of the disease is not confined to the early part of the season in that district. It appears continuously during the growing season, and growers of seed must keep roguing for it until digging time. Tubers produced by plants which become infected after the middle of the growing season are sometimes destroyed by the slimy, foul-smelling rot before digging time. Other tubers from late-infected plants cause foul-smelling, wet rot in the storage cellar.

Figure 37. Rotting of seed piece and stem, a condition caused by blackleg.

Until recently it was believed that this disease was transmitted only by the seed, but recent experiments in Minnesota have proved that the organism also exists in the soil. The control for blackleg is seed treatment every year, a crop rotation in which potatoes are not planted on the same ground oftener than once in 5 years, and delaying planting until the soil has warmed up.

FUSARIUM WILT (oxysporum) differs from the two previously-mentioned diseases in that it occurs mostly in the warmer growing districts but is sometimes found at the higher altitudes. A soil temperature of about 73° F. is optimum for fusarium wilt. The chief symptom is a wilting of the vine, which usually turns a pale yellowish color. The wilting is caused by a fungus which attacks the water-conducting tissue of the plant. The water-conducting tissue usually is killed and turns brown, and the roots of the plant usually decay. A longitudinal section of the underground stem in a wilted plant will usually show this brown discoloration. The brown ring in the stem end of potato tubers is also usually associated with this

disease, although experiments have proved that this brown ring is not a reliable indication of infection.

Fusarium is not controlled effectively by seed treatment, although new evidence shows that seed treatment may do some good. The disease is present in practically all soils of the state. Fields of potatoes which become too wet from over-irrigation are almost always ruined by this disease, although growers usually say that they have been scalded. For a number of years it has been observed that the Cobbler is more susceptible than the Triumph. Crop rotation and planting clean seed are the only known methods of control.

FUSARIUM (solani v. eumartii) is a more virulent parasite than *Fusarium oxysporum* and usually appears later in the field than oxysporum. It has commonly been found in northern Colorado and is rarely found in other parts of the state. The disease "first appears as a yellowing of the areas between the veins of the youngest leaves, accompanied by necrosis of portions of the same areas, resulting in indefinite, small, brown patches."* This condition imparts a characteristic bronzed appearance to the plant; and the symptoms may be confused with those of mosaic by the inexperienced. The vascular system, however, shows the typical deep-brown discoloration, which is usually more extensive than in oxysporum. The roots are also destroyed by this parasite. This organism does not require so high a temperature as oxysporum, infection of the roots taking place at soil temperatures from 68° to 77° F.

In the tubers, eumartii often causes a stem-end rot. "There is also a vascular discoloration, either with or without the stem-end rot, which may appear as a band a fourth of an inch wide sometimes extending throughout the tuber, with the margins of the band showing a light-brown, water-soaked appearance. This is the most common appearance of the tubers, but there are many modifications, varying from deep-black streaks to a very slight vascular discoloration."* This disease does not occur in the mountains, hence frequent changing of seed, using mountain-grown certified seed; practicing long rotations; and planting potatoes after alfalfa but never after corn, are recommended.

EARLY BLIGHT, as a rule, is not serious in this state. It is not the same as the late blight for which growers in eastern states are obliged to spray. Late blight has never been found in Colorado. Early blight occurs only in seasons when there are frequent showers and cloudy weather. In 1926 there was a rather severe infestation of the disease over the state, but usually infestations are so light that they need not give concern. The disease is caused by a fungus which attacks the leaves. The infected areas are round, brown, dead-looking spots on the leaves which, if examined closely, show concentric rings such as those of a target.

*R. W. Goss, "Fusarium Wilts of the Potato, Their Differentiation and the Effect of Environment on Their Occurrence," *Amer. Potato Jnl.*, 1936, pp. 171-180.

This fungus also causes a tuber rot in storage which does not develop until tubers have been in storage from 10 days to 2 months. Small, round, sunken, shallow spots with purplish, raised margins appear on the surface of the tuber. These spots appear corky and are easily removed from the tuber. Early blight infection takes place in the field from old, infected vines, and tuber infection occurs from spores dropped from the vines upon the soil or tuber in digging.

BACTERIAL WILT is a disease observed in Colorado for the first time in 1937. It occurs mainly in the early crop, and the Triumph variety seems to be affected to greater extent than the Cobbler. The vines wilt without much discoloration and subsequently die late in the growing season. The pith in the underground stem is destroyed by the disease. Evidence of the disease in tubers ranges from a yellowish discoloration of the vascular tissues to a wet, slimy rot. Normal-appearing tubers have completely broken down after 5 days in transit to market. Little is known at present concerning this disease. Until more information is obtained, it is recommended that growers treat their seed; rotate crops; irrigate carefully, never getting the potatoes too wet; and watch the crop for the first characteristic wilting of the vines, when the crop should be dug and disposed of immediately.

Figure 38. Severe type of mosaic, left; a healthy leaf, right.

Virus Diseases

MOSAIC is characterized by a mottling of the leaves. In other words, there are light and dark areas of color in the leaf. The mottling is in most forms accompanied by crinkling. There are several types of mosaic, including mild, crinkle, leaf-rolling, interveinal, rugose, and acuba. The yield of the infected plants is lower than that of normal plants. The tubers produced are almost always

of excellent type and appearance and are invariably selected by growers who make a practice of bin selection. The disease shows best in plants grown at temperatures below 70° F. and may be completely masked by higher temperatures. It is transmitted through the seed and is carried from infected to healthy plants by insects during their feeding. It cannot be detected in the tubers. The most effective control is the elimination of infected tubers by tuber indexing and by roguing infected plants from the field. Seed plots must be isolated by at least 300 feet from fields which contain any considerable amount of this disease.

Figure 39. Leafroll in Russet Burbank; the hill on the left is a healthy hill.

LEAF ROLL is well described by its name. The plants are dwarfed, stiff, and leathery; they turn a pale yellowish green; and the outside edges of the leaflets roll upward, forming a trough with the mid-rib in the center. Tubers produced by plants infected during the current season have brown threads through the flesh (net necrosis). This net necrosis disappears after the season during which the plant was first infected, so it cannot be used to detect leaf roll in the tubers. It is carried from plant to plant by insects. The tubers produced by leaf-roll plants, two or three small ones to the hill, are usually smooth and of perfect type, hence are ideal prizes for the bin selector. Tuber indexing, roguing isolated seed plots, or purchasing certified seed are the only methods of controlling this disease.

SPINDLE TUBER is also well described by its name. It is one of the most serious potato diseases in Colorado. The affected tubers

are elongated, round in cross section, and small in size. The colored tubers are paler in color. The eyes are usually either flush with the surface or protruding. The vine is more upright than normal, with the branches growing closer to the main stem and not so spreading as in a normal plant. The color of the plant in the case of the Triumph variety is usually darker than normal, but it is paler in Cobbler and Red McClure. The leaves lose their gloss and become dull in appearance. The leaflets are smaller and wavy along the margins. The plants are usually smaller than normal plants.

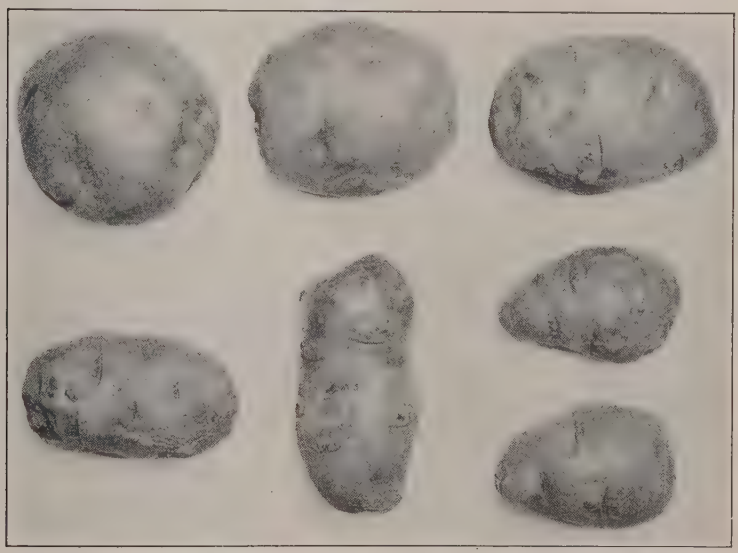


Figure 40. Three healthy tubers, top; four spindle tubers, bottom.

This disease causes a serious reduction in yield. It is easily spread by insects, by the cutting knife, and by pick planters. It can be controlled through roguing, through isolated seed plots, or by purchasing certified seed.

CURLY DWARF occurs but rarely in this state. It has been more observed in Brown Beauties in the San Luis Valley during the last 5 years than anywhere else. The name describes the disease. The plants attain a height of only about 6 inches and are mere tufts of curled, deformed leaves. Curly dwarf has not been prevalent enough to cause any serious losses so far.

WITCHES BROOM causes potato plants to become a mass of fine, weak stems, with greatly dwarfed leaflets. Extremely large numbers of tubers are produced, few of which reach one-half inch in diameter. When tubers infected with this disease are allowed to

sprout, the result is a mass of very weak, small sprouts. This condition is known as "spindle sprout.

GIANT HILL cannot be diagnosed until the latter part of the growing season. Until this time the plants appear normal. Late in the season, however, the diseased plants show up because they are taller and bloom longer than other plants. They also show up after the first frost, because normal plants will be frosted down while the giant hills will remain upright and green. They produce large, coarse tubers and often yield more tubers than normal plants. The tubers are usually abnormal in shape and are not desirable from either a market or seed standpoint. The disease was first described as a phase of spindle tuber. Field roguing and certified seed are the only methods of control for this disease.

Figure 41. Spindle sprout and witches broom are rarely found in Colorado.

Figure 42. Removing a unit of giant hill from a tuber-unit seed plot.

WILDING (HEART LEAF) has apparently not been previously described in American potato literature but seems to have received considerable attention in Great Britain. The plants are somewhat dwarfed and produce a number of weak secondary stems. The terminal leaf-

Figure 43. Leaf of wilding, left; normal leaf, right.

let is short and heart-shaped, instead of being long and slender as in the normal leaflet. The first pair of lateral leaflets is much reduced in size. The second pair is very small, and the third pair is usually entirely absent. The folioles are also usually missing. An abnormal set of tubers occurs, averaging about 40 to the hill. The tubers are somewhat longer and flatter than the normal and are extremely shallow-eyed and smooth. Wilding has occurred exclusively in the San Luis Valley, where fully 50 percent of the tubers from diseased plants go through the screen and are used for seed. The condition is perpetuated by the tubers. The method of transmission is unknown, and all attempts artificially to transmit the condition have so far met with failure. Field roguing and use of certified seed are recommended for control.

PINTO is a condition observed in the Red McClure variety. The diseased plant is larger and more rugged than the normal plant. It blossoms more profusely and sets seed balls, a process which does not occur in normal plants. The leaflets are somewhat shorter and more sharply pointed than normal leaflets. The color is more of a gray-green and is dull, whereas the normal leaflet is bluish-green and shiny. The tubers are abnormal in shape, being round in outline, short, and deep-eyed. They are very hard and are difficult to cut. Instead of being the red or pink color of the normal tuber, they are blotched red and white, hence the name. Cases of solid red tubers and solid white tubers have been observed, but they are quite rare. The yield is lower than those of normal hills. The nature of this condition and the method of transmission are not known. The control methods are field roguing and use of certified seed.

HAYWIRE is a disease which has been observed in Colorado at various times during the past 13 years. The name has been appropriated from Nebraska certification officials. The disease is a baffling one, and very little information on it is available at the present time. The first symptoms consist of a clearing and mosaic appearance in the young terminal leaves of the plant. The leaflets are narrower and more pointed than normal leaflets; later they become yellowish, with a reddish-purple color at the tips and margins. "The plants are severely dwarfed and have a rosette appearance due to a cessation of the terminal growth, a shortening of the internodes, and an increase in the number and

Figure 44. Haywire plant, right; normal plant, left.

Figure 45. Symptoms of haywire first appear in the top of the plant. Note the pinched, discolored leaflets and rosette appearance of the plant at the left; the plant at the right is a normal plant.

Figure 46. Symptoms of haywire often do not appear until the plant is fully developed. In the plant at the right, note the deformed leaves at the top, the aerial tubers, the sesile underground tubers, and light yield.

development of axillary shoots. Petioles and stems may show swellings at the nodes, with a red or purple pigmentation. Sometimes aerial tubers are formed in the leaf axils. Tubers are lacking or few and set close to the stem."*

The insidious characteristic of this disease is that seed stock from apparently normal fields may produce an appreciable percentage of it. In infected seed lots the infected tubers may fail to produce sprouts, remaining dormant; they may produce only sprout tubers, causing missing hills; the plants may emerge late and show typical vine symptoms on emergence; or symptoms may not appear

Figure 47. "Limberneck" seems to be a phase of haywire; the plant in the center is normal.

until the plants are almost fully developed. In any event, infection means a total loss. Spindling sprout has been associated with the disease by R. W. Goss. The Colorado Experiment Station has some evidence that haywire is associated with psyllid yellows, but this evidence is not sufficient to constitute adequate proof. It has been observed that adequate control of psyllid yellows will also control haywire.

Seed Treatment

Treating potato seed before planting has been neglected by most Colorado growers. The results of this negligence are everywhere evident. The Carbondale district was formerly the home of the Red

*R. W. Goss, "A Review of the Disease Problems Confronting the Nebraska Growers of Certified Seed Potatoes," *Nebr. Potato Improvement Assn., 17th Ann. Rpt.*, 1936, pp. 6-14.

McClure potato. There the soils have become so badly infected with scab that the Russet Burbank is now the only variety that can be grown on many farms. There is hardly a farm in this district or in the San Luis Valley on which a crop free from rhizoctonia can be raised. Longer rotations and seed treatment every year are necessary to prevent this disease ruining these districts. There are only three potato diseases that can be controlled by seed treatment; these are blackleg, rhizoctonia, and scab. There is now some evidence to show also that fusarium may be held in check to some extent

Figure 48. Treating potato seed on a large scale.

by seed treatment. Growers have often been misled as to the value of seed treatment, believing that seed stocks would remain productive indefinitely if the seed was treated. The virus diseases are in no way affected by seed treatment. These are eliminated from seed stocks by tuber indexing and roguing, especially in tuber-unit seed plots.

Methods

There has been a great change in the materials used for treating seed during the past few years. Growers became very impatient with the old 1½- to 2-hour soak methods and could hardly be blamed for not using them. Today instantaneous dips have removed the major objection to seed treatment, and there is hardly an excuse

for a grower neglecting it at the present time. Two instantaneous methods are now in general use.

ACID-MERCURY dip is constantly gaining favor as one of the most satisfactory methods of seed treatment. A concentrated solution for mixing with water may be purchased under various trade names, or it may be mixed at home. Dissolve 6 ounces of mercuric chloride (corrosive sublimate) in 1 quart of commercial hydrochloric (muriatic) acid; add this to 25 gallons of water in a wooden container. A 50-gallon wooden barrel is a very suitable container. Mercuric chloride is a deadly poison and will corrode metal of any kind. The concentrated acid should be handled very carefully. The diluted solution is not strong enough to injure the hands.

The potatoes should be emptied into wooden crates or wire baskets treated with asphaltum paint, and then placed in the solution. It is not advisable to treat in sacks, as the sacks weaken the solution, and the solution weakens the sacks. *The tubers should be well dried after treating.* Cut seed cannot be treated by this method. The tubers should be allowed to remain in the solution for 5 minutes but are not injured by leaving them as long as 40 minutes. Enough unused solution should be kept on hand to keep the container at its original level. From 20 to 30 sacks may be treated; then the solution should be discarded and a new one prepared.

Growers who plant late during warm weather should reduce the strength of this solution, using only 4 ounces of corrosive sublimate, as instances of poor stands have been observed when the recommended strength of the solution was used.

ORGANIC MERCURY compounds, of which there are now several on the market, including "semesan bel," are known as instantaneous dips. These materials formerly failed to control rhizoctonia, but new formulas have been developed by the manufacturers which now seem satisfactory for the control of this disease. These materials are not corrosive and may be used in metal containers. One pound in solution will treat from 20 to 30 sacks of potato seed. Picking baskets are generally used, and the operator merely makes certain that all the tubers are wet. The tubers should be thoroughly dried as soon as possible after treating or should be planted immediately. Cut seed may be treated with these materials. This procedure is especially recommended when cut seed is planted in the San Luis Valley. Any seed that is worth planting is worth treating.

Cutting Seed

There are very few growers who cut seed to the best advantage. Many hold the knife in the hand and whittle wedge-shaped pieces from the tuber at any place where there happens to be an eye. These pieces do not handle well in the machine planter and have so much surface exposed that they dry out readily. The skin of a

potato tuber is cork and is one of the most efficient coverings developed in the plant world. As much of the skin should be retained on each seed piece as possible; and each seed piece should be blocky, so that it will not readily dry out. The smaller the seed tuber the

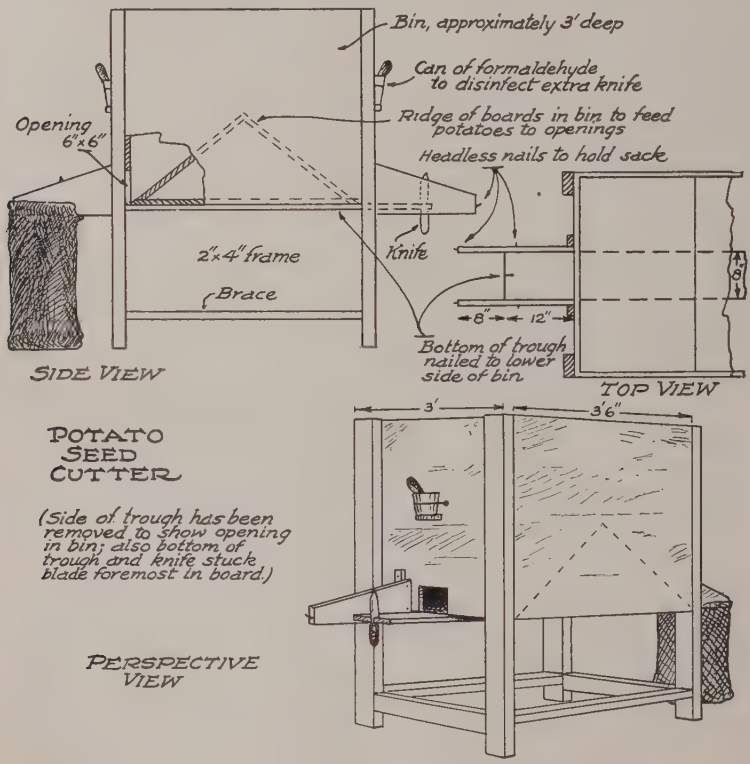

Bin, approximately 3' deep
Can of formaldehyde to disinfect extra knife
Ridge of boards in bin to feed potatoes to openings
Headless nails to hold sack
Opening 6"x6"
2"x4" frame
Brace
Knife
SIDE VIEW
8"
12"
Bottom of trough nailed to lower side of bin
TOP VIEW
POTATO SEED CUTTER
(Side of trough has been removed to show opening in bin; also bottom of trough and knife stuck blade foremost in board)
3'
3'6"
PERSPECTIVE VIEW

Figure 49. This cutting box makes potato cutting a lighter job.

less cut surface there will be. The best stands are produced by seed pieces with the least cut surface.

Machines for cutting seed have been developed but are not recommended for most Colorado varieties. If the Red McClure is cut into four equal pieces, the stem-end piece on the left side of the tuber will not contain an eye. The same is true of the Brown Beauty to a certain extent. These two varieties have very few eyes. Seed pieces should be so cut that they average from 1½ to 2 ounces in size or are about as large as a hen's egg. A board for holding the knife will make it possible to cut seed much more rapidly than by merely holding the knife in the hand. The hopper illustrated in figure 49 is used at the Mountain Substation and is very satisfactory.

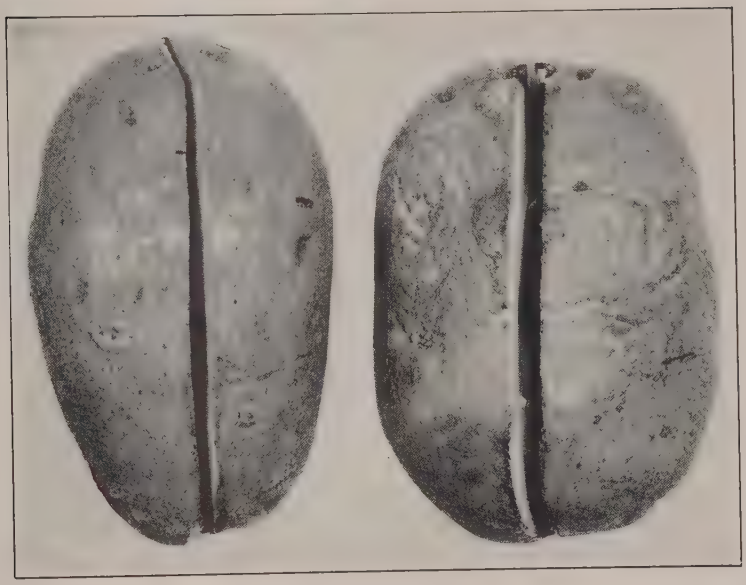


Figure 50. The first step in cutting potato seed.

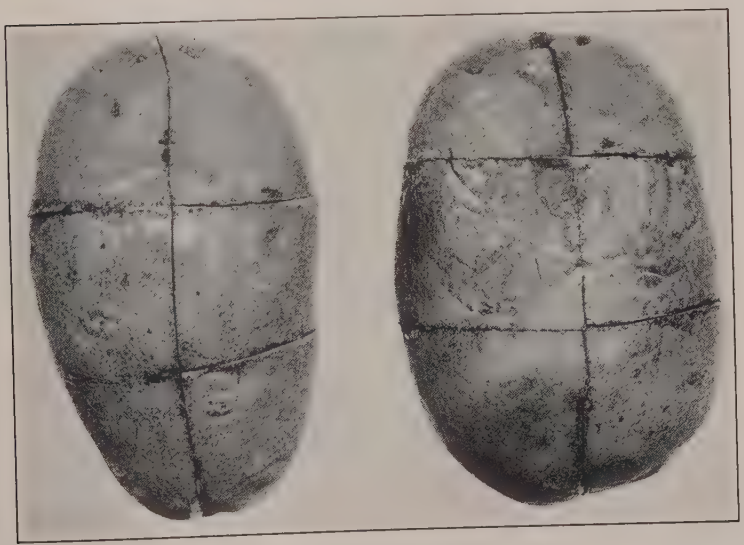


Figure 51. Finishing cutting seed potatoes into blocky pieces, 1½ ounces to 2 ounces each.

In cutting seed it is important to remember that the strongest and best sprouts come from the bud-eye cluster, so the first cut should always be made from the bud-eye cluster through the stem of the tuber, except in long varieties such as Russet Burbank. As many cuts may then be made crosswise as desired, holding the two halves of the tuber together during this process. Some growers follow the wrong practice of discarding either the stem end or the seed end, or both. While it is true that the eyes at the stem end of the tuber are more dormant than those at the seed end, experiments show that there is no significant difference in the yield. The proper method of cutting seed is illustrated in figures 50 and 51.

In some districts of Colorado it is advisable to plant potato seed as soon after it is cut as possible. In most of the mountain districts, however, seed may be allowed to set for some time without any damage, provided it is not piled so deeply that it will heat. If the temperature is kept above 50° F. and the humidity high, the cuts will heal over or suberize. The practice of sprinkling freshly cut seed with lime or with sulfur is of doubtful value. Road dust would serve just as well to absorb the excess moisture. At the Mountain Substation cut seed has been allowed to stand for as long as 2 weeks without any damage.

The amount of seed required to the acre for various-sized seed pieces and at various planting distances is given in table 13.

Planting

Many of the difficulties encountered in potato production in Colorado could be avoided if the crop were properly planted. Seed is quite often planted too deeply, and in some cases too early. In either case it lies in cold ground, germinates slowly, and is subject to attack by the soil-borne diseases, "rhizoc" and blackleg. In other cases the seed is not properly cut, or the planter is in poor repair, and a poor stand results. In 1910 a survey of the state showed the average stand to be 70 percent of a complete stand. The average stand today is very little better. It is difficult to understand why a grower will painstakingly prepare a seedbed, cultivate and irrigate with the utmost care, and yet be satisfied with a 70- to 80-percent yield. Experiments have proved that the hill on each side of a skip will make up one-quarter of the loss of one hill. So when a skip consists of more than one hill, only one-half of the yield of one hill is made up, and the others are a total loss.

Date of Planting

Potatoes are planted in Colorado from the first week in April to the middle of June, depending upon the district. Some growers in the San Luis Valley plant as early as the last week in April. The soil is still cold, germination is very slow, and many of the plants

TABLE 13.—*Pounds of seed required per acre, with various planting distances and sizes of seed pieces.*

Spacing between rows	Spacing between plants	Number of pounds per acre				
		1-ounce size	1¼-ounce size	1½-ounce size	1¾-ounce size	2-ounce size
Inches	*Inches*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
30	8	1,632	2,040	2,448	2,856	3,270
	10	1,308	1,638	1,956	2,286	2,616
	12	1,092	1,362	1,632	1,908	2,178
	14	936	1,164	1,398	1,632	1,866
	16	816	1,020	1,224	1,428	1,632
32	8	1,530	1,914	2,298	2,682	3,066
	10	1,224	1,530	1,836	2,142	2,448
	12	1,020	1,278	1,536	1,788	2,040
	14	876	1,092	1,314	1,530	1,752
	16	768	960	1,152	1,344	1,536
34	8	1,440	1,800	2,160	2,520	2,880
	10	1,152	1,440	1,728	2,016	2,304
	12	960	1,200	1,440	1,680	1,920
	14	822	1,026	1,236	1,440	1,644
	16	720	900	1,080	1,260	1,440
36	8	1,362	1,704	2,040	2,382	2,724
	10	1,086	1,362	1,632	1,902	2,178
	12	906	1,134	1,362	1,590	1,812
	14	780	972	1,164	1,362	1,554
	16	678	852	1,020	1,188	1,362
	18	606	756	906	1,056	1,212
42	18	516	648	780	906	1,038
	24	390	486	582	678	780
	30	312	390	468	546	624
	36	258	324	390	456	516
48	18	456	570	678	792	906
	24	342	426	510	594	678
	30	270	342	408	474	546
	36	228	282	342	396	456

contract "rhizoc" and blackleg, which seriously decrease the stands and lower the yields. It is very doubtful if anything is gained by planting Brown Beauties before the first week in May, and experience has shown that Red McClures are much better planted after the middle of May. When certified seed is used, Triumphs may be planted as early as the Brown Beauties. Blackleg is a more serious problem in growing Red McClures and Triumphs, and this disease is not prevalent when the soil is warm enough to insure immediate germination. Some growers have practiced planting a seed plot as late as June 28, in order to obtain small tubers for planting. The objective has not been attained, because growers who are painstaking enough to go to this trouble have fertile soils; and their efforts have resulted in market-sized tubers, despite the late date.

The Greeley district has gone to the other extreme in planting late to escape damage from fusarium, flea beetles, and Colorado potato beetles. The Colorado Potato Experiment Station at Greeley has concluded after 5 years of experimentation that the Rural New

Yorker plantings made on May 20 and June 2 tended to be superior to those made on June 12, from the viewpoints of both yield and maturity. Workers at that station also concluded that the yields of Triumphs increased with the lateness of planting, the plantings of June 12 producing much larger yields than the earlier ones. In the mountain districts plantings are generally made between May 10 and June 1. Experiments still in progress at the Mountain Substation indicate that Russet Burbanks planted between May 18 and May 25 not only produce the highest yields but the best quality. In the early districts plantings are made as early as the last week in March, although it is doubtful if it is advisable to plant before the first week in April. Crops planted as late as April 15 are often ready to harvest as early as those planted the last week of March.

Planters

There are three types of planters used in Colorado. Each type has its advantages and disadvantages. The cup type is used almost exclusively in the San Luis Valley. It is well adapted to handling whole seed but is not well adapted to cut seed, because the corners on the cut seed wedge into the cups and the piece does not fall out when the cup turns over to go down the tube. Some growers use this planter as an assisted-feed type, pulling as many as three of them with a tractor and having a man to correct the feed on each planter. It is rather difficult to use this planter in this manner, as the length of chain and the number of cups between the seed hopper and the tube are so few that a man must be very active to place a

Figure 52. Three-row cup-type potato planter and men to correct the feed.

Figure 53. Picker type of potato planter.

seed piece in an empty cup. He is also in constant danger of catching his fingers when the cup turns over into the tube.

The picker-type planter is probably more generally used than any other because of its cheapness of operation. There is no means by which a seed piece on every picker is insured, although this machine is now nearly mechanically perfect, and there are very few misses with seed properly cut and in uniform-sized pieces. The pickers jabbing into the flesh of the seed pieces are an excellent agency for the spread of any diseases seed may contain. Spindle tuber and blackleg, especially, are effectively spread in this manner. In some of the mountain districts the seed has kept so well and is so brittle that it splits when a picker sticks into it, and a missing hill is the result.

The third type of planter is known as the two-man or assisted-feed type. A conscientious man on the back end of this planter can consistently obtain a 99-percent drop. It handles both whole and cut seed equally well, provided the seed pieces are nearly uniform in size. It can be readily adapted to any size of seed piece and any spacing desired. Standard equipment on this planter is now a shallow covering device which places the seed piece in the furrow and puts just a small amount of soil on top of it, making it necessary for the young plant to come through only 2 inches of soil instead of from 6 to 8 inches, as is the case when the seed is covered with a ridge. The soil surrounding the seed warms up more quickly, earlier germination is secured, and injury from "rhizoc" and blackleg is lessened. Harrowing crosswise will level off the ground, once germination has gotten well under way. A spacing device is also obtain-

Figure 54. Two-man or assisted-feed potato planter.

able for this planter which insures a variation of not more than one-half inch between plants in the row, thus insuring a more uniform-sized crop. This same machine may also be obtained in a picker type. It may also be used for tuber-unit planting. Any of these planters may be obtained in one-, two-, or three-row units.

Depth of Planting

The San Luis Valley is probably one of the few districts in the United States where there is a tendency to plant too deep. Potatoes are sometimes planted as deep as 7 inches below the ground level. This deep planting has the same effect on the crop as planting too early. Five inches below the level is sufficiently deep, even in the sandiest soils in this district; and from 3 to 4 inches is sufficient on the heavier soils. In most other districts the planting is not deep

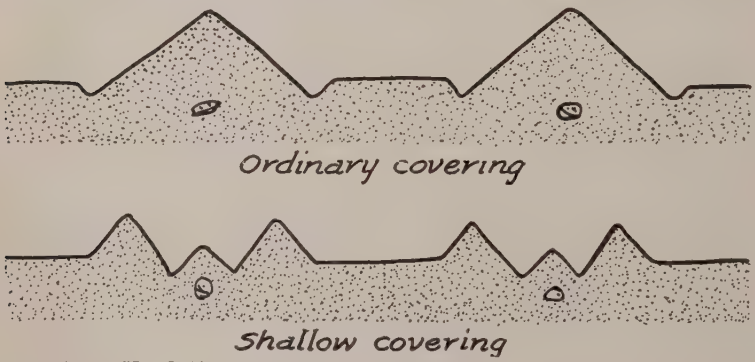


Figure 55. Ordinary covering and shallow covering of potato seed.

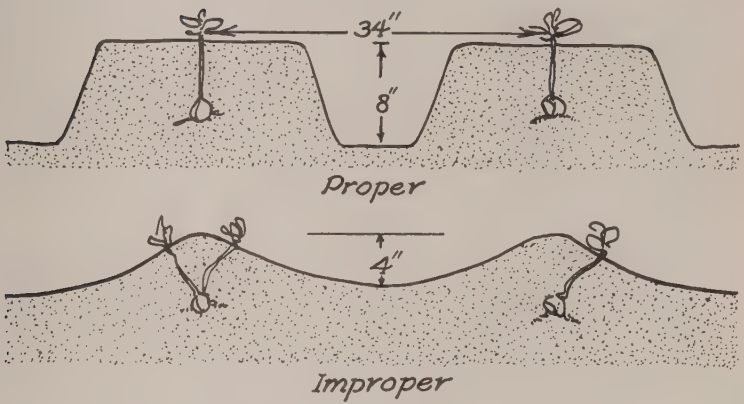


Figure 56. Good potato ridges should be broad at the top.

enough. To test the depth of planting, the ridge left by the planter should be leveled off even with the surface of the soil before planting; then dig to the seed piece and measure the distance below the level. It should be from 3 to 4 inches in heavier soils and as much as 5 inches on the lighter types. Katahdin should be planted deeper than other varieties, as this variety sets shallow and has an abnormal tendency to sunburn. Shallow planting tends to increase the amount of sunburn, as the tubers are all set above the seed piece, and sufficient soil to cover them cannot be obtained when the seed piece is at the surface of the ground.

Spacing

The chief consideration determining the distance between potato rows is the amount of soil necessary to cover the tubers. The closest possible spacing with present machinery is probably 30 inches. This close spacing is advised in the early districts so that the plants will more nearly cover the rows and shade the soil. In general, planting distances are between 34 and 36 inches, and in a few cases 38-inch rows are used. The distance between plants varies with the variety and the fertility of the soil. In Bostwick Park it is necessary to plant Rural New Yorkers as closely as 8 inches apart in the row, in order to keep the size of tubers down within reason. It is also necessary to plant Peachblows as closely as 8 or 9 inches in some districts, to prevent growth crack. Even these spacings are inadequate in some areas, and a twin-row planter has been recently developed. This machine plants two rows 12 inches apart. The pairs of rows are 34 or 36 inches apart. Cobblers are also generally planted as close as 10 inches apart on good soils. The Russet Burbank, on the other hand, is seldom planted closer than 14 inches

and is sometimes planted 16 or 18 inches apart in the row. Table 14 gives the number of hills to the acre, with perfect stand, for the various spacings.

TABLE 14.—*Number of hills of potatoes to the acre, if there is a perfect stand.*

Rows apart	8-in. hills	10-in. hills	12-in. hills	14-in. hills	16-in. hills	18-in. hills	24-in. hills	36-in. hills
Inches								
30	26,136	20,909	17,424	14,935	13,068	11,616	8,712	5,808
32	24,502	19,602	16,335	14,001	12,251	10,890	8,168	5,445
34	23,061	18,449	15,374	13,178	11,531	10,249	7,687	5,125
36	21,780	17,424	14,520	12,446	10,890	9,680	7,260	4,840
42	18,669	14,935	12,446	10,668	9,334	8,297	6,223	4,149
48	16,335	13,068	10,890	9,334	8,168	7,260	5,445	3,630

Cultivation

Cultivation is one of those potato-growing practices for which no definite rules can be made. If the seedbed has been properly prepared, 90 percent of the cultivating job has been finished. The primary object of cultivation thereafter is weed control and hilling, and root damage from excessive cultivation will materially reduce yields instead of increasing them. The practice varies with the type of soil, the growing district, and the opinion of the farmer; it depends also on whether the potatoes are irrigated or non-irrigated, and whether an early or a late crop is being grown. Growers will find it profitable, however, to harrow with a spike-tooth harrow, with the

Figure 57. The first cultivation of potatoes should be given when the plants are from 6 to 8 inches tall.

teeth laid back, two or three times between the time the crop is planted and the time when the plants reach a size of from 2 to 3 inches, to destroy early weeds. In cases where the soil is packed by the planter, a cultivation with the regular cultivator should be given as soon as the planting is finished. The number of cultivations through the growing season varies, even among the best growers. Records from the 600-Bushel Club show variations of from 2 to 10 cultivations.

The important point in cultivating is to cultivate deeply and close to the plants while they are small, getting farther away from the plants as they become larger and as their root systems expand. A new implement called the chisel has been used for the earlier cultivations in the San Luis Valley. There is one chisel point between each pair of rows, and usually four of these points are fastened to one frame and drawn by a tractor. These chisel points penetrate as deeply as 16 to 18 inches and do an excellent job of loosening the soil. This system is successful in this district because of subirrigation but can hardly be recommended where furrow irrigation is practiced, because of danger of washing this loose soil and also because of the difficulty in getting water through without getting the soil too wet.

Hilling

Two methods of culture are followed in Colorado, depending upon whether the land is irrigated or non-irrigated. The level system of culture is generally followed on the non-irrigated land, as moisture is conserved by this method. Hilling usually begins with the first cultivation, after the plants are too large for the spike-tooth harrow. The shovels on the cultivator are set so that the soil is thrown toward the plants. This smothers the weeds starting in the row and makes a ditch for irrigating. Fenders are usually provided to prevent the small plants being covered during the earlier cultivations.

During all the cultivating operations the grower should keep in mind the ideal type of ridge, which is as broad at the top as possible. There must be enough soil on top of the ridge to cover all the tubers which will be developed later. The size and shape of this ridge is of vital importance in preventing sunburn. The large yields obtained in Colorado under irrigation make the prevention of sunburn a difficult problem that can be largely solved through the proper formation of this ridge. Tubers not only come to the surface of the ground but quite often protrude from the sides of the ridge. This protrusion can be kept at a minimum only when the ridge is broad at the top. Inverted V-shaped ridges are to be avoided.

These ridges should be formed quite early; otherwise, the plants will be considerably damaged through the cutting of roots in the formation of the ridges. As soon as the plants begin to interfere with cultivation, the plants should be "laid by." The last one or two cultivations are made with disk hillers or winged shovels. The disk hillers probably make the best-shaped ridges. It is necessary to have the furrows which carry the water between these ridges deep enough that water does not come in contact with the plants or tubers. In the warmer growing districts it is not advisable to ridge

Figure 58. Level culture is recommended in non-irrigated potato areas. Hilling is not done until after the vines are killed by frost, to protect the tubers from freezing until digging is completed.

until the cool weather of late summer arrives, as more surface is exposed and the soil temperature greatly increased by high ridges, and there is a greater loss of moisture by evaporation. Many new growers make the mistake of not "laying the plants by" early enough and do more damage than good by attempting to ridge after the plants have covered the rows.

It is important to remember that the best way to cultivate is to thoroughly prepare the seedbed. The operations described in preceding paragraphs are only for controlling weeds, making ditches with which to irrigate, and providing sufficient soil coverage for the tubers. Cultivation does not increase the yield but may actually decrease it. From two to four cultivations are sufficient in most districts. In some districts, especially in the San Luis Valley, farm-

ing systems leave the land so foul with weeds that cultivation with machinery does not eliminate them, and it is necessary to pull them by hand.

Irrigation

The irrigation of potatoes is one of the most perplexing problems confronting the grower in Colorado. Unfortunately, there are very few definite rules that can be followed in irrigating potatoes. It is one of those practices which should vary because of varying soil conditions, variations in climatic conditions, and variations in the water requirements of different varieties. Considerable work has been done on irrigation practices in various states, and from the brief discussion which follows the intelligent grower can adapt these findings to his own conditions.

Definitions

To clear up some existing confusion, the following definitions are presented:

Acre-foot: The volume of water sufficient to cover an acre 1 foot deep; it equals 43,560 cubic feet.

Acre-inch: The volume of water sufficient to cover an acre 1 inch deep.

Second-foot: The equivalent of a stream 1 foot wide and 1 foot deep, flowing at the rate of 1 foot a second.

One second-foot: Approximately 1 acre-inch to the hour.

One second-foot: Approximately 2 acre-feet to the day (24 hours).

One second-foot: Approximately 450 gallons to the minute.

One second-foot: 38.4 miner's inches in Colorado.

Use of Water by the Potato

The potato is not a heavy user of water, and it has less power to exhaust the soil of its moisture than any other common crop. Workers in various states have found that the potato produced its maximum yields when from 9 acre-inches to 48 acre-inches of water were applied by irrigation. The wide fluctuation was due to soil and climatic variations. In Nebraska* it was found that the seasonal use of water by the potato crop varied from 11 to 18 inches, with an average of 14 inches (fig. 59). Each inch of available water produced about 20 bushels of potatoes. In the same series of experiments, alfalfa used

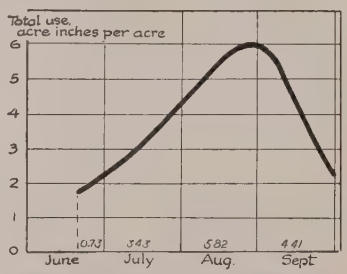


Figure 59. Average (1932-35) seasonal use of irrigation water by Triumph potatoes at Scottsbluff, Nebr., planted from June 15 to 20. The figures at the base are the inches of water used by the crop for each month. (Courtesy of Scottsbluff Field Station, U.S.D.A.)

*LESLIE BOWEN, *Seasonal Uses of Water by Potatoes and Other Farm Crops Under Irrigation* (Nebr. Potato Improvement Assn., 1935-36) pp. 31-38.

nearly 27 inches, sugar beets 24 inches, and oats 15 inches of water. In experiments in Utah it was found that the yield of potatoes was increased as the application of water increased up to 15 inches, and that the yield decreased when more than 20 inches of water was applied. Measurements at Greeley, Colo., showed that 19 to 22 inches are applied in thatdistrict.

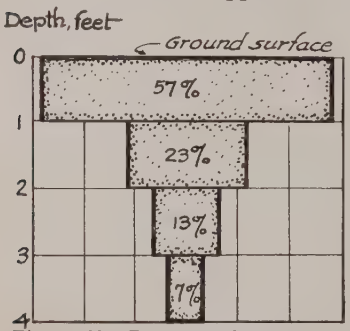


Figure 60. The use of water by the potato crop from different depths of soil, Scottsbluff, Nebr., 1932-35. (Courtesy of Scottsbluff Field Station, U.S. D.A.)

The Nebraska work shows that potatoes obtain most of their moisture from the first foot of soil (fig. 60). Under some conditions potatoes are able to obtain some moisture from the fifth foot of soil, but under irrigation 93 percent of the moisture is obtained from the first 3 feet. The object of the irrigator, then, is to maintain the moisture content of these first 3 feet above the wilting point.

The heaviest use of water by potatoes is during August. Nebraska experiments show that three-sevenths of the seasonal use is during this month. The Utah work shows also that when only one 5-inch application was made at various times during the season, that made on August 1 gave the highest yields. The blooming period is the most important period in the development of the plant. Several investigators have found that tuber set increases as the moisture increases.

When to Irrigate

Potatoes should be irrigated whenever they need it, regardless of whether they have not yet emerged, are 6 inches tall, or are in bloom. Experiments over a 7-year period at Greeley prove that withholding water until plants reach a certain stage of development not only decreases yields but also lowers the quality of the crop.

Potatoes should be kept growing continuously, and growth should not be checked by lack of water at any time. This is true not only early in the season when yields are chiefly affected but later in the season after tubers have reached some size. If checked in growth at this time, quality and appearance of tubers always suffer, the skin sets, and the tubers begin to mature. Some varieties, such as Triumph, Rural, and Brown Beauty, become long and ill-shaped; others, such as Russet Burbank and Early Ohio, become knobby; and still others, such as Red McClure, growth-crack when irrigation is resumed. When a soil has become dry, it is more difficult to wet again, so no water is saved by this practice. The experienced grower

can tell by the color of the vines when potatoes need water. The beginner should dig into the row to a depth of about a foot. The soil at this point, when squeezed, should form a ball which retains its form when pressure is relieved, leaving the hand slightly moist. The wilting of plants during the middle of the day is not necessarily an indication of a need for water. The potato is a cool-season plant, and its root system is not large enough to take care of excessive transpiration from the vine during hot weather.

TABLE 15.—*Average acre yields 1919 to 1925 at Greeley as a result of starting irrigation at various times.**

Time of irrigation	Primes	Culls	Total
	Bushels	*Bushels*	*Bushels*
When needed	291.3	21.9	313.2
Blooming	266.5	23.5	290.0
Wilting	210.2	26.2	236.4

*W. C. Edmundson, 1929, *Studies in Time and Rate of Irrigation of Potatoes in Colorado.* U. S. D. A. Tech. Bul. 118.

Flooding

In many districts winter moisture is not sufficient to insure "germination" of the seed. It is much cheaper to flood than to take a chance or to irrigate up. In some districts it is customary to spring plow, and there it is often necessary to irrigate by flooding before the ground can be plowed. In this case there is usually enough moisture remaining in the soil to bring the plants up. With fall-plowed ground it is seldom necessary to increase the moisture content of the soil before planting. Flooding of soils high in alkali salts is recommended in order to wash out some of the alkali (fig.

Figure 61. Flooding before planting insures moisture for plant emergence and removes excess alkali salts.

61). Experience has demonstrated that flooding before planting should be a standard practice in the San Luis Valley. Flooding after the crop is planted usually results in crop failure. Flooding the crop in Utah resulted in yields below those of non-irrigated lands. Flooding before emergence results in seed-piece decay; flooding because of inadequate waste ditches, or as a result of rains when the "sub" is up, results in serious losses or failure.

Irrigating Up

Irrigating up will seldom be necessary if proper precautions are taken before planting. There are occasional cases, despite all recommendations and precautions, where growers are confronted with the problem of whether or not to irrigate up. Seed will sprout in dry soil, but roots will not develop without moisture, and the plants will not emerge from the ground. Despite disastrous experiences and recommendations to the contrary, the potato grower should not hesitate to irrigate up. The furrows should be a little deeper than the seed is planted, and extreme care must be taken to confine the streams of water to these furrows. The moisture should go only to the seed piece, leaving the soil on top of the seed as dry as possible. Alternate rows should be used if the soil "subs" readily. The Colorado Potato Experiment Station at Greeley found that irrigating up in 4 different years resulted in better stands and an average increase in yield of 51.56 bushels an acre.

Amount of Water to Apply

The soil may be considered a reservoir in which water is stored between irrigations. This reservoir will hold just so much water, and it is useless to apply more than it will hold. Excesses of water are not only wasteful, but they leach out essential plant food. Tests in Utah show that about one-half the volume of soil is taken up by the soil particles themselves. The remainder is taken up by air spaces and moisture. These proportions vary to some extent with the soil type. Sandy and sandy-loam soils, when saturated, hold from 2.5 to 3 inches of water to the foot, of which 1.25 to 1.75 inches are available to plants. Clay loams and clays hold from 3.5 to 4.5 inches of water to the foot when completely saturated, of which from 2 to 2.5 inches are available to plants. As previously pointed out, potatoes obtain nearly all their moisture from the first 3 feet of soil; so when a soil is in need of irrigation, it is useless to apply more than from 3 to 6 inches in any one application, as this is all the soil will hold. The problem is to get this amount of water into the soil and get it evenly distributed.

The absorption of water by the soil depends upon a number of factors. Obviously, less water is absorbed by a soil on a steep slope than on level ground in a given amount of time. Water must be run longer to obtain the same absorption, and the waste is greater.

To obtain the maximum efficiency, decrease the size of the stream with the steepness of the slope. The state of cultivation also influences the absorption of water by the soil. Loose soils absorb water more readily than tight soils. The first irrigation is absorbed more readily than subsequent irrigations, as the furrows become puddled and sealed after the first irrigation. It is advisable to break the bottom of this furrow with a chisel point between irrigations, if possible. The amount of water in the soil also influences absorption. A soil that has become too dry absorbs water slowly. The work in

Figure 62. On soils in which water readily moves laterally, alternate rows may be irrigated early in the season. Water should never be run more than 800 feet from one head ditch.

Utah shows that the capacity of a soil to absorb and retain water is greatly dependent upon the initial moisture content.

The soil is probably the most important factor affecting the absorption of water. The sandy benchlands of Nebraska absorb water at the rate of 1.4 inches an hour, while the volcanic ashes of Idaho absorb only ½ inch an hour. In some soils, water penetrates only to a depth of 2.5 feet in 10 hours.

One of the most perplexing problems in irrigation is the lateral movement of water. In some soils, such as those of the San Luis Valley, water moves laterally quite readily, but in soils such as those of the Mountain Substation, lateral movement is very slow. It would seem from observation that the rate of lateral movement depends upon the drainage. Some soils are so well drained that

water moves too readily downward. Thorough preparation of the soil and use of small streams of water will assist lateral movement. Irrigating often and before the soil becomes too dry between irrigations will also help to overcome this difficulty.

It is obvious from the foregoing discussion that no one can tell a grower the best method of irrigating his crop. The grower must determine from experience the length of time and size of stream necessary to get from 3 to 6 inches of water into the soil on his farm, and even here there may be a difference between individual fields or even between parts of fields.

Over-Irrigation

Over-irrigation is all too common whenever and wherever plenty of water is available. Potatoes are most consistently over-irrigated in Montrose, Delta, and Mesa Counties, because this section always has plenty of water. Over-irrigation is also common in the San Luis Valley and at Greeley when water supplies are adequate. It is, in fact, quite commonly conceded by growers that the best crops are raised when the supply of water is considered not quite adequate, and conversely, that poorer crops are raised when water is plentiful. Over-irrigation reduces yields. In the Utah experiments, yields decreased as applications increased above 20 inches, until at 96 inches yields were lower than under non-irrigation. As previously

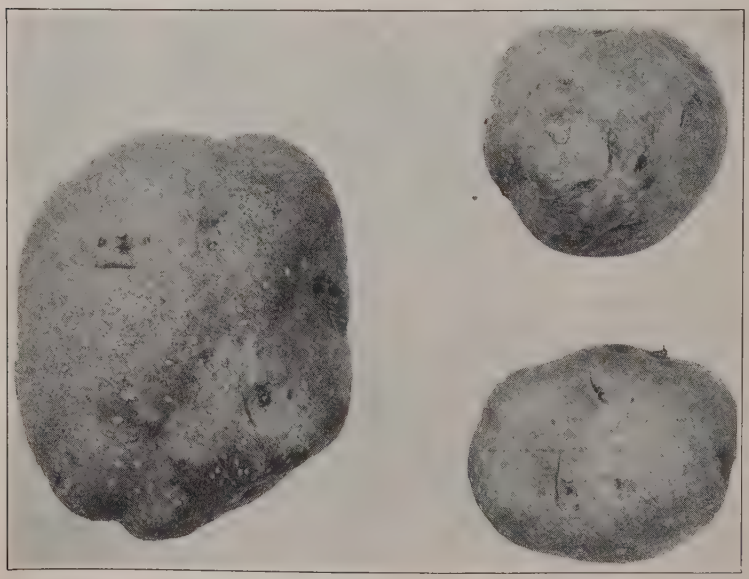


Figure 63. Tubers with enlarged lenticels such as these indicate that the crop has been over-irrigated.

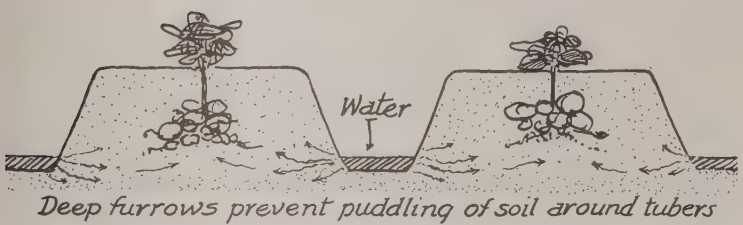


Figure 64. Water should enter below the seed piece to prevent puddling the soil around the tubers.

pointed out, only one-half the soil volume consists of soil particles; the remainder is air space and moisture. As the moisture increases, the air space decreases. Ohio experiments have shown that soil air is necessary for maximum yields of potatoes; when too much air is replaced by water, yields are reduced. Too much water also injures the quality, as the lenticels enlarge and the tubers become unattractive in appearance.

When to Stop Irrigating

Irrigation should cease in time for the tubers to mature before digging. Heavy irrigation late in the season increases the amount of "rhizoc," scab, and worm track; the skin of the tubers remains thin and tender and is damaged by digging; and too much soil sticks to the tubers. Experiments at the Mountain Substation show that very little increase in yield occurs after the first week in September; so, under similar conditions, irrigation is useless after about September 1. It will seldom be profitable, in the later districts, to irrigate after September 10.

Irrigating from Wells

Since 1931 many irrigation wells have been dug in the San Luis Valley and in northern Colorado to supplement the water supply from streams. Water from these wells is usually colder than ditch water, is clear, carries no sediment, and is absorbed by the soil more readily than ditch water; and it may carry mineral salts which are either detrimental or beneficial to crops. It is recommended that a sample of water from each well be analyzed to determine its mineral content. The water is pumped from the well into the head ditch and is then distributed by furrow irrigation. In the San Luis Valley it is recommended that the one-half-mile rows be divided into thirds for better distribution of water. Alternate rows should be used for the earlier irrigations; but in August, when the vines have reached their full development, every row should be used. The water-holding capacity of soils in the valley is very low, and many growers have not kept the soil wet enough for maximum crops. In August, potatoes in the valley should be irrigated as often

Figure 65. Irrigation wells supplement the water supply from streams in the San Luis Valley and in northern Colorado.

as the grower can get over them. Another difficulty is sealing the ditches after the first irrigation. Vine growth may interfere with cultivation to break the crust in the ditches, so water must be run longer to obtain absorption of the desired amount. The soil around the plants should be examined for moisture content and the water allowed to run until this soil is wet.

Subirrigating

Subirrigation is confined to parts of the San Luis Valley where

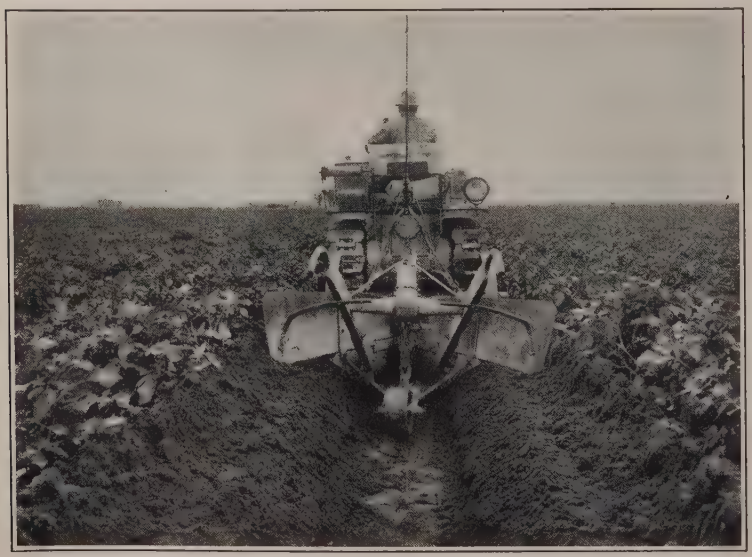


Figure 66. Making a sub-ditch in the San Luis Valley.

the water table is high and there is plenty of water. No water is run in the rows as in the furrow method. One or two rows in each 20 or 40 are skipped in planting, and a large ditch is run in this space when irrigation is to start. Water is run in these ditches and the water table raised until capillarity brings the moisture to the surface. The water table is then maintained at this level by regulating the flow of water in the ditches.

This method has many disadvantages. It takes an enormous amount of water to "get the sub up." During the past dry years growers have been unable to "get it up" or have "lost it," which

Figure 67. Subirrigation on the L. G. Schutte farm. These Brown Beauty plants were 54 inches tall on August 6 and growing an inch a day; note the absence of bloom.

resulted in serious damage to crops. A grower is not in absolute control of the moisture in his soil, as his neighbors' activities in irrigation influence his "sub." Many fields are "drowned out" by careless or excessive use of water, and heavy rains after the "sub" is up mean disaster. Its advantages are that it is economical of time and labor; an even amount of moisture is supplied throughout the season, *if properly handled* and *if the neighbors cooperate;* soil temperatures never become excessive; and the soil is never packed, puddled, or crusted.

Summary of Recommendations

1. Supply enough moisture to keep potato plants growing vigorously at all times, as a check in growth *at any time* during the season results in a loss in yield and quality.

2. Flood the soil before planting, if it is dry or if it contains excess alkali salts. This should be a standard practice in the San Luis Valley.

3. The water should be allowed to run until the "sub" comes together under the seed piece.

4. Plenty of organic matter will not only increase the water-holding capacity of the soil, but it will keep it from puddling, baking, and crusting so badly after irrigation.

5. Runs of irrigation water greater than 800 feet in length should not be made, as the upper end will become too wet before the lower end is wet enough.

6. Potatoes can be successfully irrigated up, if recommendations are carefully followed.

7. If the soil "subs" readily, water only alternate rows until the vines reach their maximum growth.

8. In heavy soils the maximum water-holding capacity is so high that developing tubers do not obtain sufficient air. These soils should not be kept saturated. Over-irrigation is too common.

9. Cease irrigating in time for the skin on the tubers to set before digging. This will also allow the soil to dry sufficiently that it will not stick to the tubers so badly.

Early Potato Production

The growing of early potatoes in the Western Slope and Greeley districts differs in some respects from general potato growing in Colorado. Earliness is often of more importance than a large yield. The sandier soils are better adapted to very early crops than are the heavier soils.

Greening the seed and planting the second week in April is much more satisfactory than putting the ungreened seed into cold ground the last week in March. Seed degenerates rapidly, so a seed plot planted with certified seed should be grown every year.

The planting distances in the early districts should be somewhat closer, as early varieties do not have such large vines and are generally not as heavy yielders as are the late varieties. The closer planting will tend to shade the ground better when the vines reach their full size and the weather begins to get warm. Fusarium or wilt is usually a menace in the early districts but can be held in check by careful irrigation.

Seed for early planting should always be treated, as cold soil favors the development of "rhizoc" and blackleg.

The early crop should never be allowed to become too wet, and growers often irrigate at night to prevent "scalding" the plants. It is advisable to irrigate lightly and frequently, using every other row; and the next time over, irrigating in the rows which were

skipped during the first irrigation. This will tend to keep soil temperatures lower and still avoid the danger of getting the crop too wet.

The Cobbler is the most satisfactory variety for early potatoes, as the Triumph tends to air-crack when dug before fully matured, and most strains are not so early as Cobblers.

The height of the ridge is best determined by the grower's experience. High ridging will warm the soil more quickly in the spring and force a rapid early growth of the plants, but it may cause soil temperatures to become too high during July.

Harvesting of potatoes begins as early as the last week in June and continues in different areas until September 1. The digger should not be allowed to get too far ahead of the pickers in harvesting, because of danger from sun-scald.

Dry-Land Potato Production

Potatoes are produced without irrigation in many parts of Colorado, and from 15 to 18 percent of the state's acreage is dry-land acreage. In some of the mountain districts methods do not differ materially from those used in irrigated districts, because the annual precipitation is above 20 inches. In the plains area, however, potato production has suffered greatly because of 5 crop failures in the past 7 years, due to drought.

There are two serious problems in dry-land potato production. The first is soil fertility; the second is soil moisture. Wind erosion and water erosion have removed much valuable top soil from these areas, and the fertility of the soil has been thereby considerably decreased. Experiments have failed so far to develop a method of replacing this lost fertility. Barnyard manure loosens the soil and causes a greater water loss, but tests show that application of 10 tons of manure per acre every 3 years is the most efficient method yet devised for maintaining the organic-matter content of the soil. Attempts to use sweetclover have failed because of the difficulty of obtaining good stands. Plowing under rye as a green manure crop has been successful, but the effect on yield needs more study. Various grasses as sources of organic matter are being tested, but it will be some time before results are available. Soil fertility has not yet become a limiting factor in potato production, and more experimental work is needed before any recommendations can be made.

Under conditions in western Nebraska* it has been found that in many years the summer rainfall is not of much benefit to the potato crop. In these years the crop is practically dependent upon the moisture stored in the soil at planting time, so that the effective precipitation from October 1 to May 31 is of prime importance in

*H. O. WERNER, 1936, *The Relation of Rainfall Distribution, Soil Moisture, and Crop Rotation to the Yield of Potatoes at the Box Butte Experiment Farm* (Nebr. Potato Improvement Assn., 1935-36) pp. 39-55.

Figure 68. A dry-land potato field on the plains where, because of limited precipitation, the highest yields are obtained by summer fallowing.

dry-land potato production. Effective precipitation is considered not less than 0.25 inches in 1 day or in 2 consecutive days. If this moisture is above normal, good crops can be produced without any summer rainfall.

Soil Preparation

The method of preparing the soil will be governed, to some extent, by the crop preceding potatoes. Nebraska* experiments showed that fall-plowed land produced 13.3 percent more potatoes than spring-disked land. Fallow produced 10.8 percent more potatoes than fall plowing. Other experiments† have shown that early fall plowing plus late disking, or early spring plowing followed by two diskings, produce best results. Medium-depth plowing—6 to 8½ inches—was better than shallower or deeper plowing. Packing after plowing gave good results, especially in dry seasons.

Rotation

Potatoes fit into the dry-land farming program very well. Crops following potatoes yield almost equally as well as crops grown on summer fallow. The work of H. O. Werner in Nebraska shows that the beneficial effects of rotation are largely a result of the residual moisture in the soil after the crop preceding potatoes is removed. Potatoes are able to draw moisture from the first 5 feet of soil, and it is only when these 5 feet of soil are well supplied with moisture that good crops can be produced. Considering 7 percent

*L. L. Zook, 1933, *Dry-Land Crop Production at the North Platte Experiment Substation*, Nebr. Exp. Sta. Bul. 279.

†H. O. Werner, 1937, *Good Stands of Potatoes: Experimental Evidence Concerning Factors Affecting Them* (Nebr. Potato Improvement Assn., 1936-37) pp. 36-50.

of moisture equal to 1 inch of water per foot of soil, Werner found that when only 2.5 inches of water were present in the first 5 feet of soil, no tubers were produced, but that 20 bushels of potatoes were produced for each additional inch of water present. From 5 to 6 inches of stored moisture produced a fair-to-good crop; and from 7 to 8 inches, or all the soil would hold, produced average yields for western Nebraska. Potatoes drew upon the first 1 to 1½ feet of moisture during July; upon the second and third, and sometimes upon the fourth, during August; and upon the third and fourth, and most heavily upon the fifth, during September.

During the dry year of 1934, potatoes following wheat, where 2.45 inches of moisture were present at planting time, yielded 5 bushels an acre; after corn, with 3.28 to 3.52 inches of moisture present, the yield was 22 bushels an acre; and after fallow, with 4.14 inches of moisture present, the yield was 81 bushels an acre. Similar results were obtained in 1936. The 5-year (1931-35) average yields of potatoes after the following crops were as follows:

	Bushels
Fallow	104.3
Corn	93.1
Beans	81.6
Potatoes	71.0
Wheat	67.1
Sweetclover	65.0

This work has also demonstrated that long rotations are necessary to control scab and "rhizoc."

The following rotations are recommended, and substitutions may be made to fit local conditions:

1. Wheat, wheat, wheat, fallow, potatoes.
2. Wheat, corn, wheat, corn, potatoes.
3. Wheat, beans, wheat, corn, potatoes.

Planting

The dry-land potato grower has a serious problem in determining the best planting date. The Nebraska Experiment Station has made a thorough study of this subject.* Its investigators found after 6 years' study that early plantings—late May and early June—usually produced larger yields, larger tubers, and tubers less likely to air-crack in harvesting and which shrunk less in storage; but the tubers were paler colored, more elongated, and contained more scab than those from later plantings—mid-June to early July. Early blight and fusarium were worse in early plantings, while "rhizoc" was worse in late plantings. Early plantings produced the best stands. On the strength of these findings the Nebraska station recommends planting between June 15 and 20: "If common scab

*H. O. WERNER, 1932, *Tuber Development in Triumph Potatoes as Influenced by Time of Planting on Dry Land in Northwestern Nebraska*, Nebr. Res. Bul. 61.

is not likely to be serious, the best time is probably about June 5. If severe scab is almost certain to occur, planting after June 20 would be best."

Deep planting—from 4 to 5 inches—gives better average results than shallow planting. In years of abundant moisture shallow planting is best, while in dry years deep planting is best. Deep covering is better than shallow covering. From 6 to 8 inches of earth should cover the seed piece. At Alliance, Nebr., stands were increased 5.5 percent by packing after planting, and plants emerged sooner.

Spacing

Rows are usually from 42 to 48 inches apart and the plants from 15 to 24 inches apart in the rows. Some adjustments in spacing can be made profitably on the basis of the moisture content of the soil at planting time. If the soil moisture content of the first five feet is high, closer planting can be practiced; if soil moisture is low, wider spacings should be used.

Cultivation

The ground should be kept as level as possible to prevent excessive loss of moisture and should not be ridged as under irrigation. It is good practice to cultivate immediately after planting and then harrow to level the ground. Any ridging of the soil simply exposes more surface to evaporation. Future cultivation is for the purpose of controlling weeds, closing cracks which may appear, and keeping the surface in such condition that it will readily absorb rainfall.

Insects

Although there are many insects which sometimes damage the potato crop, there are only a few of enough general importance to be considered here. The insects of general importance which cause the greatest losses are the Colorado potato beetle, the flea beetle, the potato psyllid, the grasshopper, the blister beetle, the wireworm, and the tarnished plant bug. Until the last 2 or 3 years, growers in Colorado have not sprayed potatoes, except for spraying for the Colorado potato beetle with crude implements. Control methods for the flea beetle and the potato psyllid have recently been worked out by the Entomology Section of the Colorado Experiment Station. There are no potato diseases in Colorado of sufficient importance to warrant a spray program, but these insect pests do warrant such a program.

Flea Beetle

The larvae of the flea beetle causes the "worm track" of potato tubers shown in figure 69. This damage is of importance mainly in the Greeley, Montrose, and Divide districts at present; but it is

Figure 69. Tubers injured by flea beetle larvae, showing worm track and slivers.

also known to occur in several other parts of the state. The adults eat small, round holes in the leaves of many plants besides the potato. These include tomato, pepper, eggplant, nightshade, bean, turnip, radish, cucumber, squash, spinach, lettuce, celery, and a large number of weeds. The insect in its different stages is shown in figure 70.

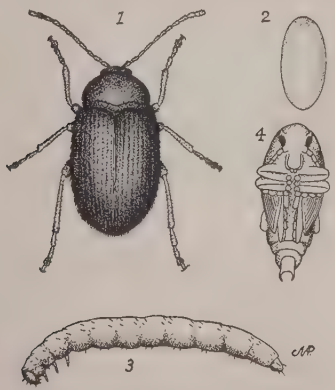


Figure 70. Potato flea beetle (1) adult x 18 (2) egg x 30 (3) larvae x 9 (4) pupa x 18.

The injury to the tuber may take two different forms, worm track and "pimples." The worm track is caused by the larvae feeding along the surface of the tuber, leaving small furrows. Scab and rhizoctonia often invade these furrows and increase the disfiguration. Treating the seed decreases materially the invasion of these organisms and lessens the damage. Pimples are caused by the larvae burrowing straight into the tubers. When a pimple is removed, a core or brown "sliver" is found which may extend into the flesh as deeply as an inch. These

are the burrows of the insects which have become filled with a brown, corky material. They increase the loss in paring as much as 8 percent.

Only 5 percent worm track is allowed in U. S. No. 1 grade of potatoes. The damage to tubers is greatest on heavy, moist soils; those from sandy soils show very little damage. In the Montrose district damage to the foliage has recently become severe enough to reduce yields. Recommended control measures have not been altogether satisfactory, and more experimental work is necessary.

The flea beetles pass the winter in the ground as beetles. They come out of hibernation the latter part of May and the first part of of June in the Greeley district. They start feeding on almost any green plant at hand. They then migrate to potato fields. When disturbed, these beetles jump and then feign death for some time, this practice making them very difficult to find.

Egg laying begins soon after the beetles emerge from hibernation in late May and early June. The eggs are deposited at a depth of ½ to 2 inches in the moist soil close around the base of the plant. Female beetles lay an average of more than 100 eggs each. Moisture is necessary for the deposition of eggs and for hatching them. The eggs hatch in about 10 days, the time depending upon temperature conditions. At higher temperatures only 7 or 8 days are required for hatching; at lower temperatures 12 days are required.

The larvae feed on the roots and tubers for about 26 days. The length of this period also is influenced by temperature. The larvae then make small cells in the soil in which to pupate. The average pupal period is about 10 days. Then a new generation of adults emerges. In the Greeley district there is one complete brood and a small part of a second, the latter being of little or no importance. No parasites have been found associated with this insect.

Flea beetles can be controlled by either spraying or dusting. Zinc arsenite, 2 pounds to 50 gallons of water, has proved to be the best material for spraying. In the Greeley district the first application should be made the first or second week in July, depending upon the planting date. A power sprayer similar to that shown in figure 76 should be used. A pressure of at least 300 pounds to the square inch should be maintained. These applications should be made at 2-week intervals. Two or three applications are necessary.

Dusting with calcium arsenate, 1 pound to 8 pounds of hydrated lime, gives very efficient control. Two or three applications are necessary and are applied at the same dates recommended for the sprays. Dusts should be applied with a duster at the rate of from 20 to 30 pounds to the acre, depending upon the size of the plants. The cost of materials for dusting is about 75 cents an acre. The most satisfactory time for dusting is in the early morning or late afternoon. A more complete discussion of flea beetles and flea-

beetle control may be found in Colorado Experiment Station Bulletin 437, "Controlling Colorado Potato Pests," by Leslie B. Daniels.

Psyllid

The potato psyllid was first associated with a disease previously known in Colorado as "blight" and "purple top" by Richards* of Utah in 1927. The insect and the disease were first identified in Colorado at Fruita in 1928, but they have since been found in practically all parts of the state. It is highly probable that the disease has been in the state since 1876, but its cause remained unknown until Richards associated the psyllid with it. There is little doubt that the disease epidemic of 1911 to 1914 was caused by this insect. There is no other potato disease or "trouble" which spreads so rapidly and uniformly nor any which causes the enormous losses that psyllid yellows causes. It has been reported from all states west of the Missouri River.

Figure 71. First symptoms of psyllid yellows. (Courtesy of Utah Experiment Station.)

The first symptom of psyllid yellows consists of an upward rolling or cupping of the basal portion of the leaflets, toward the top of the plant (fig. 71). This rolling is usually accompanied by a marginal yellowing. In Bliss Triumph and Irish Cobbler the upper parts of the plant may assume a distinct reddish or purplish color. In Brown Beauty, Russet Burbank, and Peachblow this purplish color often fails to appear, but yellowing is always evident. The symptoms spread from the top downward, involving the entire plant in severe cases. In Colorado the first symptoms generally seem to appear about the time the plants come into bloom. The

*B. L. RICHARDS, *Psyllid Yellows of the Potato*, Utah Exp. Sta. Bul., Reprint 225.

nodes of the plants enlarge, and the axillary buds are stimulated into growth, producing either an aerial tuber or a stocky shoot capped with a rosette of leaves which, when fully developed, gives the plant a compact, pyramidal shape (fig. 73). The axillary growths force the main stem to one side, giving it a zigzag appearance and making the plant appear shrunken. In Colorado these plants usually set an extremely large number of tubers, as many as 50 on Irish Cobbler being quite common. These tubers seldom

Figure 72. Psyllid: (1) adult; note the black body with white markings and the left wing which is in the normal position; (2) eggs; (3) nymph.

attain marketable size and often sprout in the soil before digging time. In other cases they sprout soon after being put in storage.

Considerable investigation has been carried on at the Colorado Experiment Station to determine the value as seed of tubers from infected plants. Such seed has not given consistent results.* Some lots have produced normal crops, while other lots have produced weakened plants with excessive axillary growth and somewhat reduced yields. Still other lots have produced as high as 30 percent spindly plants, with some dormant tubers and considerably reduced yields. Some lots also show a high percentage of haywire. From these tests it seems that planting seed from infected fields cannot

*C. H. METZGER, 1936, *Some Preliminary Notes on the Effect of Psyllid Yellows on Seed Stocks from Infected Plants*, Amer. Potato Jnl., 13:277-285.

be recommended. The entire problem, however, requires much more experimental work. Light seems to have considerable influence upon the appearance of the symptoms and the severity of the damage. An infected field was observed which had a heavy stand of volunteer oats in one corner. Few nymphs and no symptoms were present here, and a good yield was obtained, while the rest of the field was almost a failure. Rain and low temperature seem to slow the progress of infection.

The condition described is in some manner brought about by the feeding of the nymphs of the psyllid (fig. 74). Richards found that as few as from 3 to 5 nymphs might occasionally produce psyllid yellows, but full expression of symptoms seldom resulted with fewer

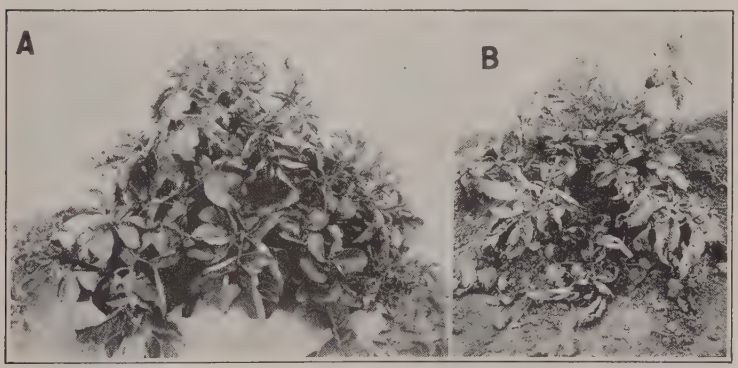


Figure 73. Irish Cobbler potato plants showing (A) severe and (B) very severe symptoms of psyllid yellows. Note the pyramidal shape of the plants. (Courtesy of Utah Experiment Station.)

than from 15 to 30 actively feeding nymphs. Five hundred nymphs to the plant have often been observed by the author. These nymphs must feed for a period of at least 16 days. If the insects are removed in less time, the plant shows a tendency to recover. Adult insects, as many as 1,000 to a plant, appear incapable of producing psyllid yellows. All attempts at transmitting the disease, other than by the feeding of nymphs of the psyllid, have met with failure. Full expression of symptoms results only when nymphs are allowed to feed continuously upon the infected plant. When Richards removed nymphs which had been feeding 26 days, the progress of the disease stopped abruptly. From this fact it would appear that some control might be obtained by killing the insects, even after 26 days of feedings. Symptoms do not appear until after the nymphs have been feeding for 3 days, and full expression of symptoms is not obtained until nymphs have been feeding continuously for 36 days. Symptoms of the disease have never been observed in Colorado in the absence of nymphs.

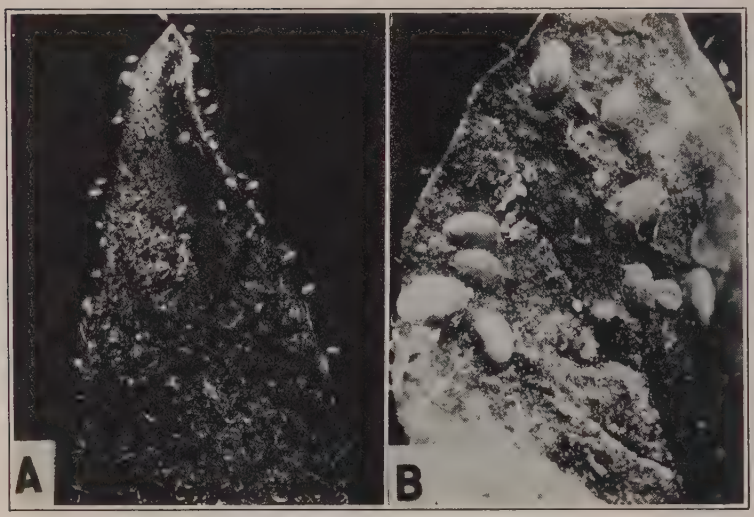


Figure 74. (A) Eggs of the psyllid; (B) nymphs feeding on a potato leaf. Note the sugar-like excrement and the different stages of development. (Courtesy of Utah Experiment Station.)

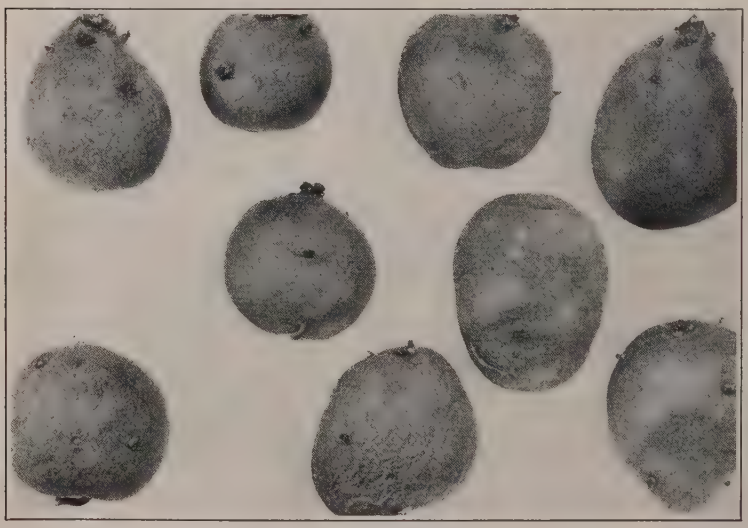


Figure 75. Brown Beauty tubers from a field severely damaged by psyllids; premature sprouting is characteristic.

The adult psyllid is a very small, fly-like insect which is very active and is known as the "jumping plant louse" (fig. 72). It can be observed only late in the fall, during cool weather. At other times it is too active to be captured. It can be readily identified on infected plants by a white "Y" on the black back of the insect. The open end of the "Y" is toward the rear end of the insect. The average life of female psyllids is about 35 days. The female begins laying eggs about 10 days after it emerges. It lays eggs for an average of about 35 days and averages about 720 eggs. The nymphs require an average of 16 days for their development. The skins are shed and the adult emerges. These skin casts can often be found on the leaves of infected plants. The small nymphs, when first hatched, are brown in color but turn green as they approach maturity.

Figure 76. A six-row power take-off tractor sprayer in operation. Three hundred pounds' pressure is recommended.

A number of parasites have been observed on this insect. It is known that the "ladybug" feeds on this insect, but is hardly possible that much control can be expected from this source because of the rapidity with which the psyllid increases. In 1933 the Entomology Section of the Colorado Experiment Station recommended liquid lime-sulfur as a control. One gallon of lime-sulfur is mixed with 40 gallons of water. A high-pressure sprayer is necessary to apply this mixture; 300 pounds' pressure should be maintained, and there should be three nozzles to each row. The first application must be made when the plants are about 10 inches tall, followed by a second application in from 10 days to 2 weeks. In sections where the infestation is unusually heavy a third application is necessary, following the second in 10 days or 2 weeks. This control insures enormous increases in yield when psyllids are present but has no effect on the yield in the absence of psyllids. It has been possible to produce satisfactory yields of potatoes at Fort Collins by spraying from two to three times with liquid lime-sulfur, and Fort Collins

Figure 77. A six-row power take-off tractor duster. This machine is adapted to the dry lands, as it eliminates the cost of hauling water.

is representative of those areas of the state where potatoes have consistently failed. For more detailed information, consult Colorado Experiment Station Bulletins 410, 411, and 437.

Grasshoppers

Potato growers sometimes experience a great amount of damage to their crops from grasshoppers, especially in eastern Colorado. These insects are controlled through the use of poisoned-bran mash. Grasshoppers feed very early in the morning. The fresh bran mash should be scattered thinly over the field about 4 o'clock each morning. The mash should not be left in piles but should be broadcast thinly through the field. Make sure that the mash is mixed properly and is not too wet. If it is too wet, it will fall in chunks and will not break up when a handful is thrown. The following formula for poisoned-bran mash is recommended:

Paris green or crude white arsenic	1 pound
Wheat bran	25 pounds
Cheap molasses	2 quarts
Water	10 quarts
Lemons or oranges	3

Grind the fruit and mix with the molasses, poison, and water, agitating the mixture thoroughly. Pour it upon the bran and mix thoroughly. The mixing can be done in a tub or a tight box. From 10 to 20 pounds to the acre are required.

Blister Beetles

These insects are commonly known as "old-fashioned potato bugs." They are long, slender insects, about four times as long as they are wide, and gray or black in color. The damage from this insect is done by the adults which feed on the foliage of the plants, often consuming all the leaves. When they first appear they are in small bands and concentrate on a few plants in a small area. At this period they may be controlled by hand picking or by knocking them into a pail of water and kerosene with a paddle. After the insects become spread out through the field, control is more difficult.

This insect is not readily poisoned, and ordinary stomach poisons have little effect. An equal mixture of hydrated lime and sodium fluosilicate, applied as a dust at the rate of from 20 to 30 pounds to the acre, has given good results.

Colorado Potato Beetle

Growers in different districts know different insects as "potato bugs." The Colorado potato beetle has black stripes on a pale yellow ground. It is rather large, being about one-half inch in diameter. The larvae are reddish colored. Both larvae and the adults are heavy feeders and will strip a vine of its leaves in a few days. This insect occurs mainly in the Greeley and northeastern districts. It does not occur on the Western Slope. Paris green has been commonly used as a control in the past but is more expensive than other materials and sometimes burns the foliage. Arsenate of lead gives satisfactory control, as do also the materials recommended for

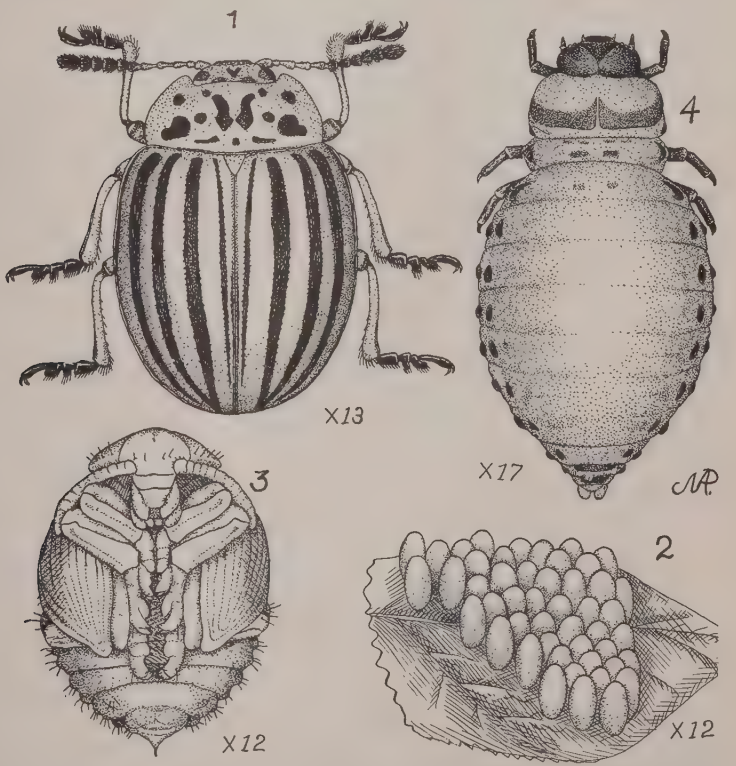


Figure 78. Colorado potato beetle: (1) adult; (2) egg mass; (3) larva; (4) pupa.

the flea beetle. Lime-sulfur and zinc arsenite may be combined in one spray for the control of flea beetles, psyllid yellows, and "potato bugs," in which case 2 pounds of zinc arsenite should be added for each gallon of lime-sulfur.

Tarnished Plant Bug

The tarnished plant bug is a soft-bodied insect a little less than one-fourth inch long and less than half as wide. It has a somewhat greenish-bronzed appearance, with a triangle just back of the head. It is a sucking insect and feeds on the tender terminal growth of the plant, causing wilting of the young leaves and sometimes death of the terminal 2 inches of the plant. Recent investigations indicate that it may produce other injuries which extend into the tubers. In most districts the damage from this insect has been slight, but in the Carbondale-Glenwood Springs area damage has been severe enough to warrant control measures. Dusting with sulfur is recommended as a repellant.

Wireworms

Wireworms are the tan-colored, tough larvae of the click beetle. They occur in some of the newer high-altitude districts of the Western Slope. The larvae bore into the seed tuber, often completely destroying it, and into new tubers, rendering them unsightly and unmarketable. Observations indicate that they may be responsible for the spread of blackleg under some conditions. It requires from 3 to 5 years for wireworms to complete their life cycle, all of which time, excepting their adult stage, is spent in the soil. This fact makes control extremely difficult. Potatoes and red clover seem to be among the most susceptible crops; hence clover should not be planted, and potatoes may not be planted oftener than once in 5 years. Fall plowing is recommended, and as many cultivated crops as possible should be included in the rotation. More experimental work on the wireworm is necessary to determine a more definite plan for control.

Other Insects

Other insects observed damaging potatoes include aphis or plant lice, cutworms, white grubs, thrips, and alfalfa and cabbage loopers. These insects cause little damage, are localized in small areas, or appear only at rare intervals.

Jack Rabbits

In drought years jack rabbits cause considerable damage to potato crops. In several cases they have destroyed entire fields. They are quite easily poisoned by strychnine mixed with salt in the proportion of 1 ounce of strychnine to 1 pound of salt. This mixture is placed in a 1-inch hole in a short piece of 2x4 and placed

near the rabbits' runway. Sometimes the 2x4 is nailed to a short stake to keep it off the ground, with a rag flag fastened to the top of the stake to attract the rabbits' attention.

Harvesting

Many excellent crops of potatoes are ruined by careless or inefficient harvesting and handling methods. This damage may consist of digger cuts, cracks, bruises, or skinning; the latter type of injury is also known as feathering. These injuries not only increase the percentage of culls but detract from the appearance of the potatoes. There is more loss in preparing them for table; there is more shrinkage; and these injuries provide an avenue for the entrance of rot organisms which cannot penetrate the sound skin of a tuber.

Mechanical injuries vary considerably, the percentage of damaged tubers ranging from 5 to 95 percent. Certain varieties of potatoes are more susceptible to damage than others. Werner* found in Nebraska that four times as many Triumph tubers as Irish Cobblers air-cracked in harvesting and that the cracks in the Triumphs were nine times longer than those of the Cobblers. He also found that 1.74 percent of the Cobblers were cut in digging and that these cuts tended to heal in storage; that an average of 4.28 percent of the Triumphs were cut, and that these cut tubers tended to rot in storage. These injuries cannot be altogether eliminated, but they can be greatly reduced if the crop is properly dug and handled.

The Nebraska Experiment Station, in a 3-year study, found that an average of 31.1 percent of all tubers harvested in 1928 were cut and air-cracked. In 1929 the percentage was 16.0 percent, and in 1930 it was 16.6 percent.

The Maine Experiment Station† found that an average of 47.81 percent of the tubers harvested in that state were mechanically injured. Of this total, 7.1 percent were major injuries—that is, severe enough to be grade defects and to throw them out of U. S. No. 1 grade. These major injuries increased to 9.65 percent after 2 months' storage. In addition to the major injuries, there were 40.71 percent of minor injuries not serious enough to affect the grade but still serious enough to damage the appearance and quality of the crop. A survey showed that mechanical injury was the most common and serious defect found in Maine potatoes. Two percent of bruising lowered the prices in Boston markets, and "15 percent of bruising lowered prices nearly one-third during the 1929-30 season." A condition as serious as this surely deserves considerable attention by potato growers.

Conditions as bad or worse than these exist in Colorado. More

*H. O. WERNER, 1931, *The Cause and Prevention of Mechanical Injuries to Potatoes*, Nebr. Exp. Sta. Bul. 260.

†WILLIAM E. SCHRUMPF, 1933, *The Effect of Handling Methods on Qualities of Maine Potatoes*, Maine Exp. Sta. Bul. 365.

attention should be given to the maturity of the crop, to soil conditions at digging time, to protection from digger injuries, to careful picking and to containers used, to careful handling from the field to storage, to careful handling in placing in bins, and to prevention of injuries in grading and in loading cars.

A crop that is fully matured is much less liable to injury than one that is immature at digging time. This maturity can best be obtained by planting potatoes early or selecting an earlier-maturing variety or strain. Growers should cease irrigating at least 3 weeks before the crop is to be harvested, as this will promote the maturing of the crop and lessen the damage in digging. Digging should also

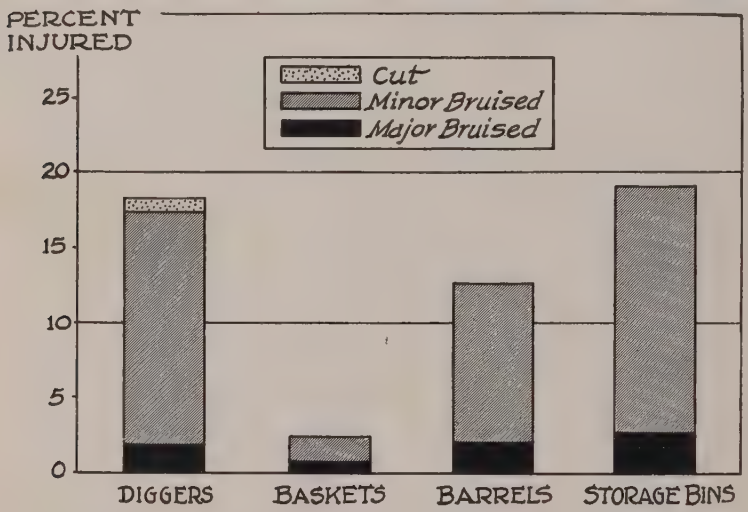


Figure 79. Injuries caused by the various operations involved in harvesting potatoes in Maine.

be delayed as long as possible without incurring danger of freezing. Werner obtained from 6 to 15 times more injury from late plantings than from early plantings. He also found that digging on September 29 produced a 24-percent injury, while 8 days later, on October 7, there was less than 5 percent injury.

Soil conditions at digging time have a decided influence on mechanical injury. When soils are too dry, clods may go over the digger with the tubers and cause considerable injury. The soil is sifted through the elevator more readily, and tubers bouncing around on the unprotected rods are injured more than those carried over with some soil. The rods are protected to some extent by a layer of soil when the soil is damp. Stones increase the amount of damage. In Maine it was found that where less than 149 stones per 100 pounds of potatoes passed over the digger, the injuries were to 9.34 percent of the tubers; where more than 450 stones passed

over with 100 pounds of potatoes, the number of tubers injured was 24.26 percent. Clods have a similar effect. In Nebraska it was found that larger tubers were injured twice as much as smaller ones. Deep planting produces more injury than shallow planting.

Diggers

Diggers are the cause of a very large percentage of mechanical injury. Manufacturers have now become aware of this condition and have designed diggers which considerably reduce the amount of injury. The best of these, however, are rather high-priced as yet and are hard to pull.

Two types of injury are caused by diggers: cuts and bruises.

Figure 80. Sorting potatoes in the field. The picker should hold the basket close to the screen, and the sorter should not be shaken while the picker is dumping.

In Maine it was found that 18.31 percent of the tubers were injured by the digger—.93 percent of the injuries being cuts and 17.38 percent bruises—of which 1.75 percent were major injuries. The amount of injury depends to a considerable extent upon the type of digger and upon the power used. In Maine it was found that horse-drawn diggers cut 1.34 percent of the tubers, engine diggers .84 percent, and power take-off tractor diggers .57 percent. Traction diggers with shakers at the rear end bruised 28.15 percent of the tubers, while horse-drawn diggers carrying gasoline engines to operate the elevators bruised 20.47 percent of the tubers. Engine-operated, continuous-elevator diggers bruised only 12.75 percent, while power take-off, continuous-elevator diggers bruised only 11.73 percent.

In Nebraska it was found that power take-off diggers injured 16.2 percent of the tubers, and horse-drawn machines injured 24.8 percent.

In addition to the power used, certain other points respecting the digger and its operation should be taken into consideration. Diggers 26 or 27 inches wide are recommended for all late varieties and for Bliss Triumphs. Narrower diggers may be used for Irish Cobblers. The digger should be low-wheeled, so that the elevator will not be so steep as to cause the potatoes to roll down. Low wheels also make it possible to dig both ways on ground which has a little slope. There should not be two aprons on the machine, as considerable bruising is caused by the drop from the elevator to the rear apron.

The digger should be redesigned so that there is one continuous

Figure 81. Full sacks ready to be "bucked" into the cellar.

chain going to the rear end. It will be necessary to build up the teeth on the drive sprocket by welding, and to provide supports for the chains under the digger to keep them from dragging on the ground. The tail of the digger should be adjustable and should be run as closely to the ground as possible. In some soils the agitators should be replaced by rollers. All places on the diggers that are struck by potatoes should be padded with old inner tubes, tires, rubber hose, or old sacks. In addition, it may be advisable to put disks in front of the digger blade, so that soil will be forced onto the digger point. If these disks are kept sharp, they may also serve to cut off large vines which interfere with operation of the digger as well as bruise the tubers.

Picking

The amount of damage caused by picking up potatoes and by subsequent operations may be materially reduced by allowing the

tubers to lie on the ground for from 1 to 4 hours. This allows the tubers to dry, permits the skin to toughen, and reduces the amount of earth carried into cellars. In Maine it was found that 2.22 percent of the tubers were damaged by being dropped into splint baskets. In Nebraska 45 percent of the tubers were cracked by tossing them into unlined baskets, while only 25 percent were cracked when baskets were lined with one or two layers of burlap. When tubers were allowed to dry for 25 minutes, only 12.5 percent were cracked by placing in lined wire baskets. Tubers are not only injured by the baskets but by falling upon other tubers. Dropping a distance of only 12 inches cracked 59.5 percent, and the cracks were more severe than when the tubers merely hit the basket. A delay of 40 minutes in picking reduced the percentage of tubers cracked to 13.3 percent.

Figure 82. Padding the bare wire basket or using the new, rubber-covered wire basket prevents many bruises.

The next operation, emptying the potatoes from the basket into a sack or barrel, causes more damage than picking up. In Nebraska from 3 to 60 percent of the tubers were damaged when emptied into sacks. In Maine 8.16 percent were damaged by emptying into barrels. In Nebraska 19.7 percent were cracked when dropped 30 inches, but none were cracked when dropped only 12 inches. After drying 30 minutes, a 12-inch drop produced little damage, and a drop of 30 inches cracked only 4.9 percent.

These facts lead to the following recommendations for preventing injuries in picking up: The tubers should be dug from 1 to 3 hours before picking; a longer time is desirable where possible. Extreme care and considerable judgment are required in Colorado, however, as bright sunshine and high temperatures produce sun scald. There is particular danger from sun scald in the San Luis Valley and in early districts. Baskets should be lined with one or two layers of burlap, or the new rubber-covered baskets should be used.

Screening in the field is also a serious source of damage and in many districts of the state is not practiced for this reason. No figures

are available on the damage caused by grading in the field. The pickers should not be allowed to dump potatoes into sacks from an upright position, but should carefully roll them into the sack, especially when putting the second basketful into each sack.

Handling from Field to Storage

Hauling from the field and dumping into bins produced more injury in Maine than did any other operation. A total of 19.12 percent of the tubers were damaged, of which 2.65 percent was major injury and 16.4 percent minor injury.

The practice of "spouting" the tubers through the roof into the bins, which is done also in some parts of Colorado, produced more injury than driving into the cellar and emptying the potatoes into the bins.

Observance of the following recommendations will reduce injury in getting potatoes from the field into the storage bin: The less the sacks are handled the less injury there will be. The "buckers" should grasp the half-sacks close to the potatoes, in order to keep them from rolling around. The potatoes should not be dropped or thrown into the wagon or truck. It is well to line the wagon or truck with straw or sheep pelts. A low-wheeled wagon is best for moving potatoes from the field. The "buckers" should not be allowed to walk over the potatoes, either in the sacks on the wagon or truck, or when emptying them into the bin. The best method of filling bins is to dump the potatoes carefully, starting at the rear end and putting in a layer about a foot deep. A plank should then be put across the bin not more than 2 feet above the surface of the potatoes and another layer a foot deep put in, and so on until the bin is full. The old practice of "tailing" the potatoes out of the sacks with a throwing motion should not be tolerated.

Figure 83. Harvesting in half-sacks for dumping into the cellar in bulk.

Figure 84. Dumping potatoes through a spout in the roof is an obsolete practice; tubers are immature, and workmen should not be allowed to walk upon them. Present markets demand uninjured, mature, and nice-appearing potatoes.

Full Sacks

Full sacks in the field are usually associated with sorting in the field. This method may be used where the potatoes are very well matured or where they are to be shipped directly from the field. The sorter should be well padded at all places where the potatoes strike. The sorter should not be shaken when pickers are emptying baskets onto the screen. Pickers should be instructed to empty the baskets carefully. Pads should be placed under the sacks on the sorter to prevent bruising the first tubers which drop into the sack. The sacks should be well filled and tightly sewed. Many growers claim that they can lose all their sacks from deterioration in storage and still be money ahead, because of the smaller amount of damage incurred by this method. *These sacks should not be used for marketing the crop* and must be brought up to full weight before shipment.

Storage

The object of potato storage is to keep the tubers from freezing and in a dormant condition, with as little loss as possible from rots and shrinkage, until they can be marketed. Growers most commonly store in anticipation of higher prices later in the season. Storage also makes possible the more uniform movement of the

TABLE 16.—*Comparative Colorado prices of potatoes by crop years.*

Year	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
	Dols.	Dols.	Dols.	Dols.	Dols.	Dols.	Dols.	Dols.	Dols.	Dols.	Dols.	Dols.
1910	0.80	0.70	0.60	0.53	0.54	0.60	0.60	0.70	0.77	1.22	1.70	1.62
1911	1.35	.98	.90	.94	.90	.95	1.02	1.20	1.46	1.40	1.15	.94
1912	.70	.55	.46	.38	.35	.39	.42	.36	.30	.34	.49	.69
1913	.70	.62	.63	.62	.60	.60	.60	.58	.58	.74	.86	.88
1914	.81	.72	.62	.48	.50	.58	.57	.63	.71	.73	.86	.82
1915	.54	.42	.48	.58	.70	76	.80	.95	1.05	1.18	1.33	1.39
1916	1.00	1.03	1.30	1.30	1.38	1.94	2.20	2.28	2.58	2.57	2.44	1.86
1917	1.13	.88	.90	.94	1.06	1.04	.85	.64	.51	.51	1.20	1.68
1918	1.32	.97	.88	.88	.76	.70	.66	.77	.83	.76	1.20	1.60
1919	1.55	1.50	1.58	1.62	1.81	2.26	2.74	3.30	4.28	4.50	4.00	2.65
1920	1.23	.94	.76	.70	.60	.56	.64	.68	.67	.81	.96	1.10
1921	1.03	.90	.81	.66	.77	.80	.70	.64	.55	.62	.70	.88
1922	.76	.48	.41	.32	.41	.40	.34	.45	.43	.41	.96	1.28
1923	.95	.74	.65	.64	.71	.65	.65	.70	.71	1.80	1.50	1.20
1924	.60	.53	.51	.52	.63	.64	.80	.77	.85	1.13	1.66	1.52
1925	1.14	1.10	1.88	1.73	1.93	1.78	1.75	2.30	1.80	1.45	1.40	1.05
1926	1.10	1.15	1.30	1.25	1.30	1.10	1.10	1.15	1.35	1.70	2.00	1.40
1927	.85	.65	.60	.60	.55	.55	.80	.80	.60	.55	.75	.65
1928	.55	.35	.45	.45	.45	.40	.45	.45	.45	.50	1.00	1.20
1929	1.15	1.10	1.15	1.15	1.10	1.15	1.20	1.20	1.40	1.50	1.15	1.05
1930	.85	.70	.70	.60	.60	.55	.50	.60	.55	.50	.75	.70
1931	.35	.30	.30	.30	.29	.26	.27	.28	.28	.32	.43	.28
1932	.26	.22	.24	.25	.24	.24	.26	.34	.34	.38	1.20	1.15
1933	.75	.48	.48	.48	.65	.75	.65	.50	.44	.42	.75	.60
1934	.65	.50	.55	.60	.60	.57	.54	.65	.75	.90	.90	.48
1935	.36	.32	.55	.47	.46	.49	.55	.75	.80	1.35	1.50	1.15
1936	1.05	.90	1.00	1.00	1.30	1.35	1.25	1.20	1.15	....	....	....

crop to market throughout the winter. It is not always a profitable practice for the grower, however. A study of table 16 shows that in 13 of the 27 seasons the highest prices received by growers were in October and November. In five seasons the highest prices for the late crop occurred between January and March. In the other nine seasons the highest prices were obtained after April 1. In five of these nine seasons the total United States crop was very much below normal, and excellent profits resulted from storage. In the other four seasons, however, the price differences between fall and spring were not great enough to pay the cost of storage.

This cannot be used as an argument for selling from the field, as it is impossible to dispose of the entire national crop at that time.

Figure 85. Adobe-type house used in the San Luis Valley, where dug cellars cannot be used because of the high water table.

In seasons of large crops, the very fact that so great a part of the crop was moved to market at digging time had a depressing effect on the market during practically the entire winter. This depressing effect was overcome only twice in 22 years—in 1917 and 1927. In 1916, 1919, and 1925 enormous profits were made by storage. The most satisfactory plan is to market part of the crop at intervals throughout the season. The plan of constantly holding for higher prices is almost as unsatisfactory as "dumping" the entire crop on the market at digging time. In 1925 and in 1933 too many growers held their potatoes too long. A short crop became a long one, because supplies at the end of the season exceeded possible consumption, and toward spring prices dropped sharply.

The most common types of storage cellars are illustrated in figures 8, 85, 86, and 87. The interior arrangement, however, should be practically the same in all types. The most important factor in the interior arrangement is the circulation of air within the cellar. False floors should be provided for the bins; 2x4's on edge at right

angles to the driveway, with 1x4's or 1x2's on edge 1 inch apart forming the floor, will provide adequate air space under the bins (fig. 87). These false floors should be built in sections small enough to handle, as they must be removed occasionally so that dirt and trash may be removed from beneath them. A false back-wall made of the same materials should also be provided. This insures air circulation around the entire pile of potatoes.

For bulk storage, double-slatted partitions between bins should be provided, or square-slatted ventilators should be placed at 6-foot intervals along the center of the bin. The closing of the entrance to the bins is most easily accomplished by boards resting on short 2x4's nailed to the posts and placed at an angle of 45 degrees (fig. 87). These boards may be put in place as the bin is filled or may be removed independently when emptying the bin. The contents of a bin may be determined by dividing the number of cubic feet of potatoes by 1.224, the number of cubic feet required for a bushel. In the case of sack storage, no bin partitions or bin fronts are necessary. Many growers claim that less loss and damage result from sack storage and that they can afford to lose all the sacks in which the potatoes are stored.

Figure 86. The single-entrance, bank-type storage cellar.

Temperatures

Each potato cellar should be provided with two or three thermometers which should be read often, especially at times when there are wide fluctuations in weather conditions. Potatoes freeze at 26° or 28° F. but for safety temperatures should never be allowed to get below 30°. After the first 2 months, temperatures above 40° will cause sprouting. The temperature then should be kept between

30° and 40°, with 36° to 38° as the ideal point. Tubers kept at about 32° degrees for a period of time have a sweet taste when cooked but lose it when stored at temperatures from 70° to 75° F. for a week. Disease organisms do not work as rapidly at the lower temperatures. All lots of potatoes have more or less mechanical injury as a result of harvesting and placing in the cellar. These injuries will heal or cork over in about 2 weeks, if the temperature remains between 50° and 60°, and if moisture is present. No attempt should be made to bring the temperature below 40° until 2 weeks after the crop has been put in storage. Potatoes have a dormant period

Figure 87. Interior of a large storage cellar, showing the bin fronts.

of about 2 months, unless injured by psyllids, so there is no danger of sprouting at this time.

Humidity

Dry cellars cause excessive loss of moisture from the tubers. A relative humidity of 90 percent is desirable. A high relative humidity is necessary for the healing of wounds when the potatoes are first put in storage. Growers in Nebraska have found it desirable to wet down the bins and driveway before the potatoes are stored. The driveway is also wet down at intervals during the winter, whenever it gets dry. This practice maintains a satisfactory humidity and prevents excessive shrinkage. Potatoes go through a "sweat" when first placed in storage, and they lose some moisture then. If the proper humidity and temperature are maintained, this should

be practically all the moisture loss until April, May, or even June, depending on the locality. Seed potatoes should be kept dry when the temperature starts to rise in the spring, as moisture hastens sprouting.

Ventilation

The importance of ventilation with fresh air for stored potatoes has undoubtedly been greatly over-emphasized. Many intricate ventilation systems have been devised to keep a constant stream of outside air flowing through the cellar. The only object in introducing outside air is to regulate the temperature. Too much outside air simply increases the shrinkage. Plenty of opportunity for the air enclosed in the cellar to circulate should be provided as described previously. It is best to admit cold air under the bins, as condensation of moisture on the tubers results from admitting it at the top of the cellar.

Shrinkage

Under good storage conditions the loss from evaporation of water should not be greatly in excess of 2 percent. Records on losses in storage have been kept for 2 years at the Mountain Substation. The Russet Burbank and Peachblow varieties were used. The tubers were sorted to U. S. No. 1 grade and stored in sacks even-weighted to 100 pounds each. They were re-sorted and weighed on May 15, with the following results:

	Weight Loss	*Rots*	*Total*
Russet Burbank	3.6%	4.0%	7.7%
Peachblow	4.7%	8.5%	13.2%

Monthly weighings showed that practically all the weight loss took place in the first 2 months and the last month of the storage period.

Light

The storage house should always be kept dark, as light causes the tubers to green and impairs their eating quality, although it does not injure them for seed. Many growers allow the doors on the cellar to remain open for long periods in the fall, in order to lower the temperature. Severe "light burn" or greening is always the result.

Fumigation

In cases where good seed is used and there is no field frost, growers in Colorado have little trouble with wet rots, but dry rot is always a problem. This trouble is caused by one of the fusaria which cannot enter the skin of a sound tuber but enters through a cut or bruise. More care in harvesting greatly assists in controlling this disease. Healing the wounds at the first of the storage period

as described is also a great aid. Temperatures between 32° and 36° F. prevent rapid growth of the organism. The disease is spread by seeds or spores which are very fine, dust-like particles, almost invisible to the naked eye. These live over from season to season in the storage house and in old sacks. Cellars should be fumigated every year to kill these spores. The following formula and method of use are recommended:

> Use 11 ounces of formaldehyde (40 percent), 11 ounces of potassium permanganate crystals, and 9 ounces of water to 1,000 square feet of space. Place the formaldehyde and water in a large receptacle in the cellar, add the potassium permanganate, and *leave the cellar immediately.* Close the cellar tightly, and leave it closed for several days or a week.
>
> For a cellar 75x40x10 feet in dimensions, 30 batches of this material are required. The containers should all be placed and the water and formaldehyde added to each; then close one end of the cellar tightly and add the potassium permanganate to each as quickly as possile, going toward the open door at the other end. *Leave the cellar immediately* and close the doors tightly.

Marketing

Potato growers must remember that good appearance in potatoes is more important to the purchaser than good cooking quality. The demand for bright-skinned, well-sized, clean tubers, free from defects caused by diseases, insects, or handling, has led to a number of new practices. Packages have become smaller, and uniform-sized

Figure 88. New branded bags and cars so loaded that the sacks are still in place when they arrive at their destination help sales in terminal markets.

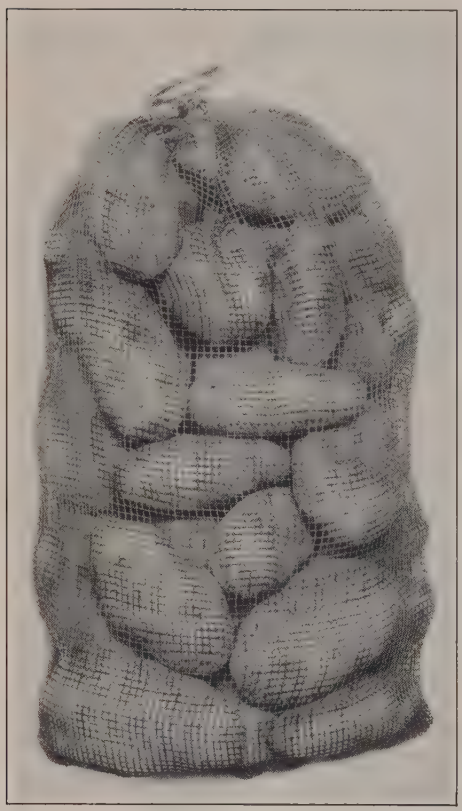


Figure 89. Small packages (10 and 15 pounds) are becoming more popular.

potatoes are placed in them; growers in some states now wash or brush the tubers to remove all dirt. New branded bags should always be used, and many growers are using colored twine to increase the attractiveness of the package.

Grading

The term "grading" covers a "multitude of sins" and consists of anything from running the tubers over a screen to remove the small ones to hand-picking for special packs. Colorado has compulsory inspection on potatoes, and as a result all potatoes are sold on the basis of the U. S. grades, which consist of U. S. Fancy, U. S. Extra No. 1, U. S. No. 1, U. S. Commercial, U. S. No. 2, and Unclassified. A designation for size is also provided for all but the first two grades. Other grades may be either size A or size B. U. S. No. 1 grade is not fancy in appearance nor difficult to attain, if potatoes are properly grown and handled.

The grading process is a source of as much injury to tubers, according to the Maine investigations,* as all the other harvesting operations together. The total percentage of damage in Maine was 43.56 percent of the total tubers, of which 7.30 percent was major injury and 36.26 percent was minor injury. The grading process caused more injury than moving potatoes to the graders or dropping them into sacks. This injury was reduced nearly one-half by padding the graders and padding beneath the sacks. Inspectors in Colorado report serious damage also from the loading of potatoes in cars. Sacks should never be dropped into place but should be carefully handled at all times.

†WILLIAM E. SCHRUMPF, 1933, *The Effect of Handling Methods on Qualities of Maine Potatoes*, Maine Exp. Sta. Bul. 365.

Figure 90. The penalty of improper grading: regrading a car before shipment.

Cleaning Tubers

Two machines which improve the appearance of potatoes are now on the market. One is a washer which is being used very successfully in California. Washed California potatoes topped the markets during the fall of 1933. Maine has been using a brushing machine since 1931. Idaho also has shipped a considerable quantity of washed and "cleaned" potatoes. This competition has forced Colorado growers to adopt the practice, and washed stock has brought a 10-cent premium on the market.

Figure 91. Loading a few cars in the San Luis Valley; notice the inspector's car and table.

Figure 92. Trackside storage and grading plant.

Potatoes as Feed for Livestock

As markets become more discriminating and in years of surplus production, the potato grower is faced with the problem of disposing of his culls and perhaps of higher grades. Numerous experiments indicate that any low-priced potatoes can be profitably fed to livestock. In European countries potatoes have been fed to livestock for many years, and special high-yielding, large-sized varieties have been developed for that purpose. Potatoes fed in livestock rations are, in a general way, comparable to corn silage. A comparison of the digestible nutrients furnished by potatoes and other feeds as reported by Morrison and Turk are given in table 17.

TABLE 17.—*Digestible nutrients in potatoes and other feeds.*

Feed	Dry matter	Digestible crude protein	Total digestible nutrients	Nutritive ratio 1:
	Percent	*Percent*		
Raw potatoes	21.2	1.1	17.1	14.5
Corn silage, well matured	26.3	1.1	17.7	15.1
Wet beet pulp	9.3	0.5	7.4	13.8
Corn No. 2	85.2	7.1	81.7	10.4

Potatoes are low in protein, so some protein-rich supplement must be included in the livestock ration when liberal quantities of potatoes are fed. Potatoes are also lacking in sufficient quantities of vitamins A and D. Both vitamins and protein are provided by well-cured alfalfa hay.

For furnishing digestible nutrients, from about 400 to 450 pounds of potatoes are required to equal 100 pounds of an average grain mixture. Roughly, the value of potatoes is 25 percent of the price of grain.

About 300 pounds of potatoes will supply as much total digestible nutrients as will 100 pounds of alfalfa hay. In other words, potatoes are worth a little more than one-third as much as hay.

Livestock should always be accustomed to potatoes gradually, as they may not be very palatable. Large amounts of raw potatoes will sometimes cause scours or indigestion, but little difficulty will be experienced if they are fed according to recommendations.

Potatoes for Beef Cattle

Potatoes fed to fattening cattle and to beef breeding cows at the Colorado, Washington, and Idaho Experiment Stations have been worth about 80 percent as much a ton as corn silage when fed with alfalfa hay. Cattle can safely consume from 15 to 20 pounds to the head daily. Potatoes are best fed raw, but if so fed they should either be chopped or fed in low troughs under a pole to prevent choking. Only 2.5 pounds to the head should be fed at the start, gradually increasing the amount to the full 20 pounds in about 10 days. In Colorado experiments 437 pounds were required for 100 pounds of gain when potatoes were fed with barley, linseed-oil cake, and alfalfa.

Figure 93. Calves fattened on cull potatoes, barley, linseed oil meal, and alfalfa at the Colorado Experiment Station. They gained practically 2 pounds to the head daily.

Potatoes for Dairy Cows

Considering the experimental evidence as a whole, it would seem that potatoes can be safely fed to milk cows in amounts not exceeding 35 pounds to the head daily, with good results. They may replace all or a part of the corn silage and part of the grain mixture, from 4 to 5 pounds of potatoes replacing 1 pound of an average grain mixture; they may also be used as a substitute for part of the hay, at the rate of 3 pounds of potatoes for each pound of alfalfa hay replaced. If fed immediately after milking, they will not taint the milk nor affect the butter. One report says that potatoes not only checked the natural decrease in milk flow but actually increased the milk yield. They should be fed raw and chopped. A recommended ration using the maximum amount of potatoes is:

20 pounds good-quality mixed hay
30 pounds potatoes
10 pounds grain mixture (18 percent total protein)

Potatoes for Sheep

Potatoes can be profitably fed to fattening lambs or breeding ewes to take the place of such wet feeds as corn silage, roots, or wet beet pulp. A summary of 11 experiments conducted at the Colorado, Idaho, Nebraska, and Washington Experiment Stations shows that the addition of cull potatoes to a ration of grain and legume hay, with or without a protein-rich supplement, has usually increased slightly the gains of lambs. On the average, 1 ton of potatoes was equal in feeding value to 185 pounds of grain plus 12 pounds of cottonseed meal and 430 pounds of alfalfa hay. If hay is valued at one-half the price of grain per ton, then cull potatoes are worth 21 percent as much per ton as grain. When fed raw and either whole or chopped, 2 pounds to the head daily, 550 pounds of potatoes were required for 100 pounds of gain when fed with corn and alfalfa.

Potatoes for Swine

Raw potatoes fed to hogs have only two-thirds the value of an equal weight of cooked potatoes. The potatoes should be salted, thoroughly cooked, and the water drained off. As a partial substitute for grain in well-balanced rations for pigs, 350 pounds of cooked potatoes, weighed before cooking, are equal to 100 pounds of shelled corn or other concentrates. To obtain satisfactory results it is not advisable to replace more than one-half the grain in the ration, and the proportion of potatoes should not be greater than 4 pounds to 1 pound of concentrates.

Some good source of protein is essential, and from ½ to 1 pound to the head daily of a mixture by weight of 50 percent tankage, 25 percent cottonseed meal, and 25 percent alfalfa meal is recommended, in addition to all the grain and cooked potatoes the pigs will eat. Alfalfa hay fed in racks may replace alfalfa meal.

Potatoes for Horses

Horses seem to be more easily affected by raw potatoes than are cattle or sheep, but small quantities—from 3 to 5 pounds daily—seem to have a beneficial effect on the general condition of the horse. Work horses can be safely fed as much as 12 pounds daily for each 1,000 pounds of live weight, but the quantity should never exceed 20 pounds daily.

Notes

COLORADO STATE COLLEGE

FORT COLLINS, COLORADO

STATE BOARD OF AGRICULTURE

J. W. GOSS, *Pres.*.....Pueblo
R. F. ROCKWELL, *Vice-Pres.*..Paonia
THOMAS J. WARREN...Fort Collins
MRS. MARY H. ISHAM....Brighton
JOHN J. DOWNEY.....Cortez
D. J. HARMON.....Fleming
J. P. McKELVEY.....La Jara
O. E. WEBB.....Milliken

Ex-officio { GOVERNOR TELLER AMMONS
PRESIDENT CHARLES A. LORY

OFFICERS OF EXPERIMENT STATION

CHARLES A. LORY, M.S., LL.D., D.Sc.....President
E. P. SANDSTEN, Ph.D.....Director
L. M. TAYLOR.....Secretary
ANNA T. BAKER.....Executive Clerk

EXPERIMENT STATION STAFF

Agronomy

Alvin Kezer, A.M., Chief Agronomist
David W. Robertson, Ph.D., Agronomist
Robert Gardner, M.S., Associate (Soils)
Warren H. Leonard, M.S., Associate
Dwight Koonce, M.S., Associate
L. A. Brown, Ph.D., Associate
Robert Whitney, B.S., Assistant (Soils)
Otto Coleman, M.S., Assistant
Ralph Weihing, Ph.D., Assistant

Animal Investigations

George E. Morton, M.S., in Charge
H. B. Osland, M.S., Associate
R. C. Tom, M.S., Assistant
John O. Toliver, M.S., Assistant

Botany

L. W. Durrell, Ph.D., in Charge
Bruce J. Thornton, M.S., Associate
E. W. Bodine, M.S., Associate
C. G. Barr, Ph.D., Associate
A. O. Simonds, Ph.D., Assistant
W. A. Kreutzer, M.S., Assistant
J. L. Forsberg, M.S., Assistant

Chemistry

J. W. Tobiska, M.A., in Charge
Earl Douglass, M.S., Associate
C. E. Vail, M.A., Associate
Earl Balis, B.S., Assistant (on leave)

Civil Engineering

E. B. House, M.S., in Charge
Adrian R. Legault, B.S., Testing Engineer

Mechanical Engineering

J. C. Strate, M.S. in M.E., in Charge
E. M. Mervine, M.E., Agr. Engineer, U. S. D. A.

Entomology

Charles R. Jones, Ph.D., in Charge
Miriam A. Palmer, M.A., M.S., Associate
Leslie B. Daniels, M.S., Associate (on leave)
John L. Hoerner, M.S., Associate

Home Economics

Inga M. K. Allison, M.S., in Charge

Horticulture

A. M. Binkley, M.S., in Charge
E. P. Sandsten, Ph.D., Horticulturist
C. H. Metzger, M.S., Associate
George A. Beach, B.S., Assistant
Louis R. Bryant, Ph.D., Associate

Irrigation Investigations

Ralph L. Parshall, B.S., Sr. Irrig. Engr., U. S. D. A., in Charge
Carl Rohwer, B.S., C.E., Assoc. Irrig. Engr., U. S. D. A.
William E. Code, B.S., Associate
Maxwell Parshall, B.S., Meteorologist

Pathology and Bacteriology

I. E. Newsom, D.V.M., in Charge
H. W. Reuszer, Ph.D., Associate Bacteriologist
Frank Thorp, Jr., D.V.M., Ph.D., Assoc. Pathologist
A. W. Deem, D.V.M., M.S., Assistant
G. S. Harshfield, D.V.M., M.S., Assistant
Elizabeth Heiss, Ph.D., Assistant

Poultry

H. S. Wilgus, Jr., Ph.D., in Charge

Range and Pasture Management

E. W. Nelson, M.S., in Charge
Clinton H. Wasser, B.S., Assistant

Rural Economics and Sociology

L. A. Moorhouse, M.S., in Charge
R. T. Burdick, M.S., Associate
D. N. Donaldson, M.S., Associate
Olaf F. Larson, M.S., Associate
R. C. Whitney, M.S., Assistant

Seed Laboratory

Anna M. Lute, A.B., B.Sc., Seed Analyst

Horticultural Substations

Herman Fauber, M.S., Supt., Rocky Ford
Ralph Manuel, B.S., Supt., Avon
Ferris M. Green, B.S., in Charge, Austin

EXPERIMENT STATION EDITORIAL SERVICE

James R. Miller.....Editor

BULLETIN SERVICE

The following late publications of the Colorado Experiment Station are available without cost to Colorado citizens upon request:

Popular Bulletins

Number	*Title*
422	Colorado Fattening Rations for Cattle
423	The Parshall Measuring Flume
424	Grape Growing in Colorado
425	Timber Milk Vetch as a Poisonous Plant
426	Oiled-Gravel Roads of Colorado
427	Insects and Mite Pests of the Peach in Colorado
428	Pyrethrum Plant Investigations in Colorado
429	Poisonous and Injurious Plants of Colorado
430	Oat Production in Colorado
431	Barley Production in Colorado
432	Western Rose Curculio
433	Equipping a Small Irrigation Plant
434	Improving the Farm Wagon
435	North Park Cattle Production—An Economic Study
436	Fitting Sheep Into Plains Farming Practices
437	Controlling Colorado Potato Pests
438	Proso or Hog Millet
439	Dry-Land Grasses and Clovers
440	Seal Coats for Bituminous Surfaces
441	Plant Propagation
442	Colorado Lawns
443	Home-Made Farm Equipment
444	Rural Households and Dependency
445	Improving Colorado Home Grounds

Press Bulletins

89	Some Injurious Plant Lice of the American Elm
91	Western Slope Lamb Feeding
93	Controlling the Squash Bug